Electronic Home Energy Reports: A Bust for Energy Conservation?

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Abstract

Home energy reports (HERs) have been shown to reduce electricity consumption via peer-comparisons, but evidence has also emerged that treatment heterogeneity and small effect sizes may undermine their cost-effectiveness in some contexts. Using data elicited from a randomized control trial in Austria, we employ a novel model specification that captures heterogeneity according to treatment intensity, measured as the deviation between the household's pre-treatment electricity consumption and the mean electricity consumption of households in its zip code. Based on a large sample of about 9,000 eco-electricity households, our results indicate that HERs induce no significant change in electricity consumption, both on average and across consumption deciles.

JEL Codes: D12, D83, Q41.

Keywords: Social norms, Energy conservation, Randomized field experiments, Non-price interventions.

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1 Introduction

A large number of studies have shown that social norms affect people's choices and induce people to save energy (see e.g. Schultz et al., 2007; Nolan et al., 2008; Ferraro and Price, 2013; Brent et al., 2015). Home energy reports (HERs), which are either sent by post or electronically via e-mail, provide households with energy conservation tips and social norm information by comparing a household's energy use to that of its neighbors. Through regular exposure to neighbor comparisons, HERs are intended to nudge reductions in household energy consumption.

This paper explores the efficacy of HERs in reducing household electricity consumption in Austria. As a Member State of the European Union (EU), Austria has committed to a binding target of a 55% reduction in economy-wide greenhouse gas emissions by 2030 compared to 1990 (EU, 2018). With increased electrification being a key pillar in reaching this target, the impact of HERs on household electricity consumption assumes central relevance. Evidence from the U.S. suggests that HERs reduce electricity consumption on the order of 2 to 5% (see e.g. Allcott, 2011; Allcott and Rogers, 2014; Henry et al., 2019), but whether equally large effect sizes apply to other countries remains an open question. Andor et al. (2020), for example, argue that the U.S. may pose a special case owing to its high levels of average electricity consumption and of carbon intensity in electricity production. Based on a randomized control trial (RCT) of HERs in Germany, they find considerably smaller effect sizes, and conclude that HERs would only be cost-effective when targeted at highly-responsive subgroups.

The question of targeting has arisen in several other studies that probe heterogeneity in responses to norm-based interventions. One strand of literature has focused on heterogeneity with respect to baseline consumption levels, with the majority of these studies finding stronger effects for high-consuming households, both for electricity consumption (see e.g. Allcott, 2011; Ayres et al., 2013; Andor et al., 2020) and water consumption (see e.g. Ferraro and Price, 2013; Brent et al., 2015). Hence, targeting HERs to highly-responsive households may render them cost-effective. Targeting becomes particularly important in the presence of what social psychologists call boomerang effects (Clee and Wicklund, 1980), when cost-effectiveness is undermined by low-consumption users increasing their consumption after receiving a HER. Social-norms theory has long recognized that such unintended responses can arise from people's desire to avoid deviant behavior, which would explain why those whose energy consumption is below the social norm would increase consumption in response to a HER. Drawing on the focus theory of normative conduct (Cialdini et al., 1991), Schultz et al.'s (2007) pioneering analysis of electricity consumption among a sample of 290 California households shows that the boomerang effect can be eliminated by including an injunctive message conveying that energy conservation is pro-social.

Injunctive messaging – usually represented with smiley and frowny emoticons – has since become a regular feature on HERs, and has generally been effective in eliminating boomerang effects. For example, Allcott (2011), Henry et al. (2019), and Andor et al. (2020) all find no evidence for a boomerang effect in households' electricity consumption. Ferraro and Price (2013) and Brent et al. (2015) likewise find no significant boomerang behavior in their studies of norm-based HERs on residential water consumption in the U.S. By contrast, Ayres et al. (2013) and Byrne et al. (2018) both uncover evidence for boomerang effects in electricity consumption from the U.S. and Australia, respectively, despite using injunctive messaging. Both studies conclude that conservation policy should target HERs to high-consuming households. Ho et al. (2016) argue that boomerang effects are consistent with cognitive processes referred to as moral licensing and moral cleansing, by which (im)moral behaviors in one domain are compensated by offsetting behavior in another (Dütschke et al., 2018). Exploring these processes using contingent valuation and laboratory experiments in the U.S., they find that the effect of social comparisons is asymmetrical, with the moral licensing effect among those better than the norm being larger than the moral cleansing effect among those below the norm. They conclude that this asymmetry calls into question the efficacy of nudges.

Another smaller strand of literature points at the context-dependency of HER-efficacy beyond baseline consumption levels. Costa and Kahn (2013) analyse the role of ideology and find that HERs are two to four times more effective with political liberals and environmentalists compared to conservatives in the U.S. Testing HERs in a large RCT among college residents who do not pay for energy bills, Myers and Souza (2020) find that HERs induce almost no behavioral change in heating demand, indicating that typical mechanisms driving conservation, such as competitiveness, social norms or moral suasion, may not work without monetary incentives.

Building on this body of work, the present study assesses the effect of electronically transmitted HERs using data elicited from a randomized control trial of over 9,000 eco-electricity customers. By examining eco-electricity customers, we further scrutinize the context-dependency of HERs. On the one hand, the presumable environmental orientation of eco-consumers may lead them to engage in voluntary restraint (Kotchen and Moore, 2008), resulting in less electricity consumption (Costa and Kahn, 2010). On the other hand, eco-consumers may be more responsive to energy conservation nudges (Costa and Kahn, 2013).

A second distinguishing feature of our analysis is in its specification of heterogeneity. The standard approach – used in all of the cited studies examining HERs – captures heterogeneity by interacting indicators for different percentiles (e.g. deciles) of baseline consumption with the treatment. We additionally employ a specification that allows for differential treatment effects according to deciles of the *deviation* between the household's pre-treatment electricity consumption and the average electricity consumption of households in its zip code. This measure allows us to isolate the social norm channel through which HERs affect how strongly households perceive that their consumption behavior is good or bad depending on their deviation from their peers.

Our results reveal no indication that HERs lead to significant electricity consumption changes, neither on average, nor upon allowing for heterogeneity. We conclude that caution is warranted in reliance on HERs as a climate mitigation tool, thereby corroborating recent findings that call into question the cost-effectiveness of HERs in countries with low consumption levels (see Andor et al., 2020). Our null-results, which persist even for high-consuming households, suggest that the eco-electricity customers in our sample are not responsive to energy conservation nudges.

2 Data

This data was collected as an extension of the data analyzed by Andor et al. (2020) under the auspices of a project whose aim was to analyze the effect of non-pecuniary instruments on electricity consumption of private households. While Andor et al. (2020) analyze data from urban households in Germany, the present data comprises the electricity consumption of 9,039 customers of an eco-electricity provider in Austria. The survey commenced in 2013, when households were randomly assigned to the treatment and control group, with the former receiving up to four electronic HERs on a quarterly basis through 2016.[1] Consumption data is available for two billing periods: a baseline period in which no household received any treatment, and a treatment period in which treatment households received the HER by e-mail. Each HER provided the treatment households with energy savings tips and a social comparison component. The latter consisted of a comparison of a household's consumption level with the mean consumption level of all households in the same zip code (see Figure A1 in the appendix), accompanied by an injunctive message conveyed through smiley emoticons.

[1]We have stratified randomization based on the following baseline electricity consumption bins: 0–1,000; 1,000–2,000; 2,000–3,000; 4,000–5,000; 5,000–6,000; 6,000–10,000; 10,000–20,000 kWh.

Table 1: Descriptive Statistics for the Estimation Sample.

	All	Control	Treatment	t-Statistic
Daily baseline consumption, in kWh	7.70	7.72	7.68	-0.41
Length of baseline period, in days	309.72	309.98	309.46	-0.24
Number of households	9,039	4,533	4,506	

In Austria, as in many European countries, households only receive a single electricity bill per billing cycle, with a billing cycle commonly lasting about one year. During the billing cycle, households' electricity prices typically remain unchanged. As meter readings in Austria are annual, the social comparison information could not be updated in each HER but was repeated based on the most recently available annual electricity consumption in each report. As pointed out by Andor et al. (2020) for the similar case of Germany, this design feature might lead to somewhat lower conservation effects but is necessary and unavoidable when testing the effectiveness of HERs in the Austrian context. In our sample, the number of days between the two metering points, i.e. the billing cycle, in the baseline period amounts to about 310 days for both the treatment and control groups (Table 1). To account for deviations in the lengths of billing periods and to make electricity consumption levels comparable between households and periods, we divide consumption data by the number of days of the respective billing period to arrive at a household's average daily consumption data.

The average baseline electricity consumption amounts to 7.70 kilowatt hours (kWh) per day and does not differ significantly between treatment and control group. Hence, annual consumption levels of our eco-electricity customers average around 2,810 kWh and are thus below average electricity consumption figures for the Austrian population of about 4,002 kWh (Statistik Austria, 2021). Two factors likely account for this difference: First, about half of our sample (and thus more than the share of the population in Austria, which is about 1/3) lives in Vienna, which is a large city where households are often smaller than the Austrian average. This is confirmed by our consumption levels being of similar magnitude and even a little higher than the average consumption level of 2,300 kWh of the German sample in Andor et al. (2020), in which the target area is a city. Second, our sample very likely consists of environmentally-friendly households, i.e. people who deliberately chose an eco-electricity provider for environmental reasons. These "environmentalists" might already exhibit voluntary consumption restraints.

Given these specific consumption characteristics of our sample, one challenge posed by our data may be the identification of small effect sizes. Andor et al. (2017) conducted a power analysis of the data collected in Germany, revealing that, after dropping extreme consumption outliers, a sample size of 5,000 households is needed to estimate consumption reductions of at least 1% with a power of 80%. Being an extension of the German data, no power analysis informed the required sample size of the present data. However, given that the consumption levels of the Austrian data are slightly higher than the German data analyzed by Andor et al. (2020), coupled with that fact that our sample size exceeds the minimum identified by Andor et al., 2017 by some 4000 households, sufficient power is not deemed a pressing concern.

3 Methods

We employ a difference-in-differences (DiD) estimator to determine the average treatment effect (ATE) of HERs on electricity consumption. Our analysis proceeds in three steps, starting with a baseline model specified as:

$$\Delta Y_i = \alpha + \beta * T_i + \tau_w + \epsilon_i, \tag{1}$$

where, following Allcott (2011), $\Delta Y_i = (Y_i^T - Y_i^B)/Y_{i,c}^T$ corresponds to the change in daily electricity consumption of household i before (Y_i^B) and after the HER treatment (Y_i^T), normalized by the average post-period control group consumption ($Y_{i,c}^T$). T_i is the treatment dummy that equals unity for households that received the HER and ϵ_{it} denotes an idiosyncratic error term. β is the coefficient of interest capturing the ATE, expressed as average electricity savings as a percentage of the average consumption level. We include weekly dummies, τ_w , for both the baseline and treatment period to account for seasonality.[2] Since the HERs were sent as e-mail to all treatment households on the same dates, but the final billing periods started and ended at differing dates for individual households, treated households received a varying number of mails in the treatment period. About 50% of treated households received between one to three mails, with the remaining 50% receiving all four mails (Figure A2). For our main model, we define the treatment dummy $T_{min.1}$ equal to unity as soon as a treated household received at least one mail within the treatment period. To test the robustness of simultaneously looking at households that differ with respect to the number of HERs received in the treatment period, the treatment dummy T_{all4} is used in another specification and equals unity only if treated household received all four mails in the treatment period. Treated households that received less than four mails are dropped in this specification, such that the control group always consists of those households that received no HER.

To explore heterogeneous treatment effects with respect to the electricity consumption level, we hone in on the social comparison component of the HER. Following several studies (e.g. Allcott, 2011; Brent et al., 2015; Byrne et al., 2018), we begin with a model that interacts the treatment dummy with dummies indicating the household's decile of baseline electricity consumption $D_{Y_i^B}$:

$$\Delta Y_i = \alpha + \beta * T_i * D_{Y_i^B} + \tau_w + \epsilon_i. \tag{2}$$

Model 2 allows for differential treatment effects according to the household's absolute level of consumption. However, it does not reveal how treatment effects may vary depending on a household's consumption level in relation to other households in the zip code, which is the core channel through which the HER is intended to incentivize

[2]The weekly dummies for the baseline period equal 1 if a pre-treatment week falls into the billing period of a household, the weekly dummies for the treatment period accordingly equal 1 if a treatment week falls into the billing period of the household.

conservation. To capture this channel, we specify a model that interacts the treatment dummy T_i with deciles of the deviation of the mean baseline consumption within a zip code from the household's baseline consumption, $(Y_i^B - \bar{Y}^B)$:

$$\Delta Y_i = \alpha + \lambda_1 * T_i + \lambda_2 * T_i * D_{Y_i^B - \bar{Y}^B} + \tau_w + \epsilon_i. \quad (3)$$

The expression $\lambda_1 + \lambda_{2,d_h} * (Y_i^B - \bar{Y}^B)$ from Model 3 captures treatment intensity, defining how strongly the mean baseline consumption within a zip code deviates from a household's baseline consumption. With this specification, we estimate conditional average treatment effects for households in different deciles h of the deviation of the mean baseline consumption in a zip code from their own baseline consumption. This formulation thus captures what households see in the HER and measures how strongly households react to their own energy consumption after seeing the social comparison, akin to the measure of relative culpability analysed by Ho et al. (2016).[3]

4 Results

Table 2 presents the results from Models 1 and 2, estimated on households that received at least one mail. The small and statistically insignificant coefficient of 0.079 from the baseline specification of Model 1 in the first column suggests that electronic HERs do not affect the electricity consumption of the sampled households. This conclusion additionally holds in the more flexible specification of Model 2, which allows for differential treatment effects by consumption decile. Notwithstanding a few statistically significant interaction effects, the marginal effects presented in Figure 1 reveal no discernible pattern of the treatment across the deciles, only one of which – in the 4th decile – just reaches statistical significance at the 5% level. This lack of evidence for significant consumption reductions across all baseline consumption groups contrasts with

[3]For the case of carbon emissions, Ho et al. (2016) define relative culpability to be the amount of social damage resulting from an individual's actions relative to damages caused by others.

several other studies showing that high-consumption households react more strongly to the social norm intervention. One exception is Henry et al. (2019) analysis of electronic HERs in the U.S., which likewise finds no evidence for heterogeneous effects according to baseline consumption.

Table 2: Average treatment effect (ATE) on households' electricity consumption.

	Model 1		Model 2	
	Coeff.	s.e.	Coeff.	s.e.
$T_{min.1}$	0.079	(0.335)	1.281*	(0.739)
$T_{min.1} * Baseline_2$	–	–	-0.290	(0.998)
$T_{min.1} * Baseline_3$	–	–	-2.363**	(1.012)
$T_{min.1} * Baseline_4$	–	–	-2.949***	(1.115)
$T_{min.1} * Baseline_5$	–	–	-0.630	(1.109)
$T_{min.1} * Baseline_6$	–	–	-2.500**	(1.192)
$T_{min.1} * Baseline_7$	–	–	-1.787	(1.286)
$T_{min.1} * Baseline_8$	–	–	-0.796	(1.379)
$T_{min.1} * Baseline_9$	–	–	-2.016	(1.589)
$T_{min.1} * Baseline_{10}$	–	–	1.496	(1.998)
Constant	1.871	(8.867)	6.823	(7.760)
Baseline dummies	No		Yes	
Week controls	Yes		Yes	
R^2	0.0880		0.1067	
Observations	8,994		8,994	

Notes: Robust standard errors are in parentheses. *, ** and *** denote significance at the 10, 5, and 1 % level, respectively.

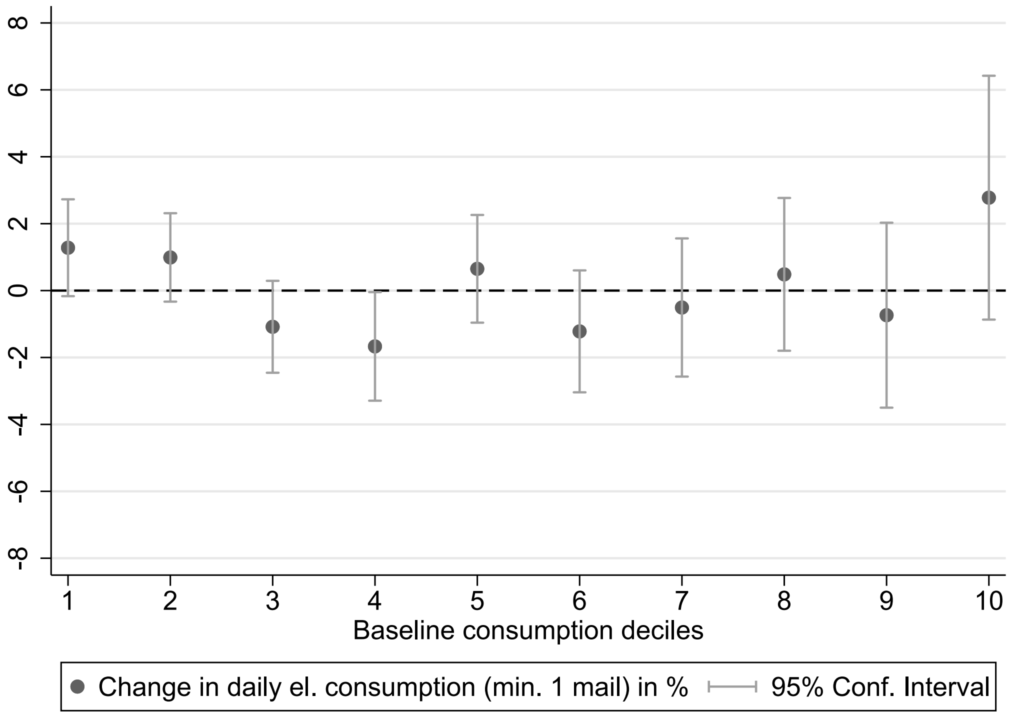
Table 3: Average treatment effect (ATE) on households' electricity consumption according to zip code deviation.

	Model 3	
	Coeff.	s.e.
$T_{min.1}$	-0.234	(0.958)
$T_{min.1} * Deviation_2$	0.919	(1.207)
$T_{min.1} * Deviation_3$	0.234	(1.204)
$T_{min.1} * Deviation_4$	-0.815	(1.274)
$T_{min.1} * Deviation_5$	0.085	(1.283)
$T_{min.1} * Deviation_6$	-0.890	(1.373)
$T_{min.1} * Deviation_7$	1.025	(1.432)
$T_{min.1} * Deviation_8$	1.189	(1.440)
$T_{min.1} * Deviation_9$	-0.914	(1.541)
$T_{min.1} * Deviation_{10}$	2.115	(2.059)
Constant	6.011	(7.101)
Deviation dummies	Yes	
Week controls	Yes	
R^2	0.1077	
Observations	8,994	

Notes: Robust standard errors are in parentheses.

To test whether merely looking at baseline consumption levels masks other drivers

Figure 1: Effect of HER according to baseline consumption deciles.

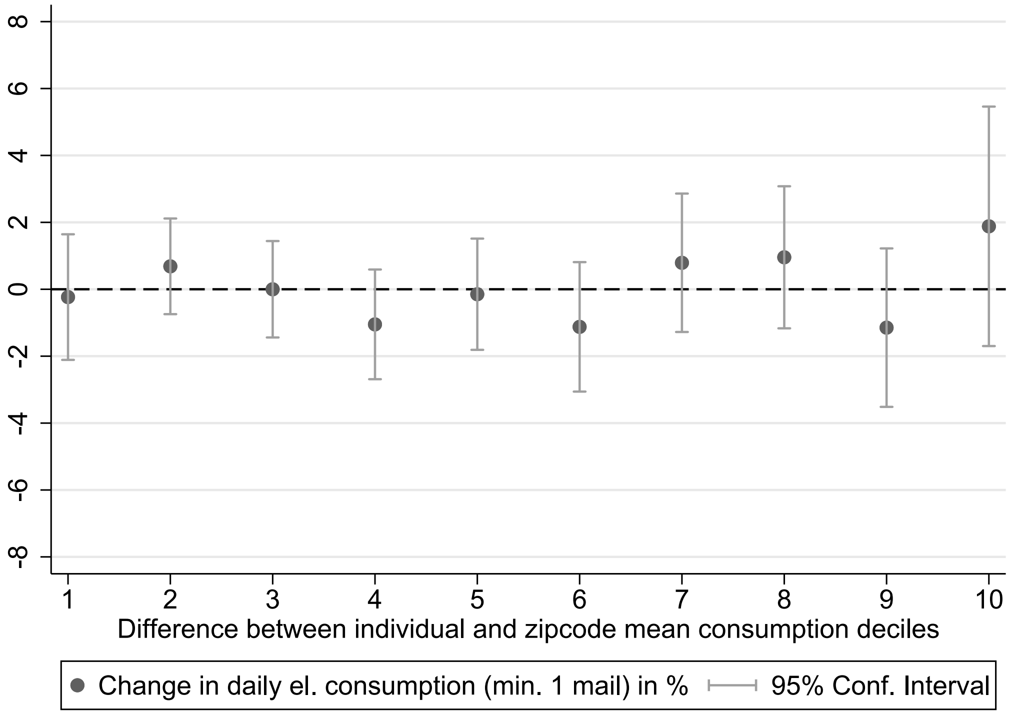


of heterogeneity, we turn to Model 3, which aims to capture the intensity of the core channel of HERs, the social norm comparison. To this end, Model 3 allows for differential treatments effects according to the deviation of the household's baseline electricity consumption from the mean level in its zip code of residence. That specification corroborates the null results from the previous specifications as can be seen from the results presented in Table 3. None of the interactions is significantly different from zero. Further insight into this heterogeneity can be gleaned by examining the marginal effects corresponding to different levels of the deviation, presented in Figure 2.[4] The marginal effect sizes lie between a reduction of about 1.5% in the 4th decile and an increase of 1.9% in the 10th decile, but none of the marginal effects is statistically significantly different from zero. Given our large sample size and size of confidence intervals which mainly span between two to three percentage points, our estimates appear to be rather precise zeros. Our confidence intervals lie in the middle of the ones by Allcott

[4]Deviations of 10 kWh can be seen at the lower and upper end of the difference between households' consumption and the zip code mean. However, 95% of the sample show deviations between -6.3 and $+5.3$ kWh per day, with only 5% depicting deviations below or above those levels.

(2011) which span about one percentage point and the ones by Byrne et al. (2018) which span about ten percentage points. In sum, we do not find any evidence for significant consumption changes after treating eco-electricity customers with social norm-based HERs. Our results indicate no significant reduction, but also no significant boomerang effect as would be indicated by a significant increase in consumption levels.

Figure 2: Effect of HER according to deviation deciles of mean zip code consumption from individual baseline consumption.



As a robustness test, we show that our results do not change substantially when restricting the sample to households that received all four mails. The baseline effects on electricity consumption from the estimation of Models 1 and 2 are slightly smaller and remain statistically insignificant (Table A1 and Figure A3 in the appendix). The results for Model 3 based on this sample also confirm our previous results and reveal no significant changes across different groups of deviation of the mean zip code consumption from a household's baseline consumption (Table A2 and Figure A4 in the appendix).

5 Conclusion

This study examines changes in household's electricity consumption following the receipt of electronic home energy reports (HERs). Based on an RCT in Austria, our results indicate that on average, electronic HERs do not lead to significant changes in electricity consumption of Austrian households. Given the recent findings by Andor et al. (2020), which point out that effect sizes are too small to make HERs a cost-effective instrument to reduce household consumption in Germany, our null results support this finding despite looking at cheaper, electronic HERs. In contrast to Andor et al.'s (2020) findings from Germany suggesting that HERs should be targeted to high-consumption households, we do not find any significant consumption reductions in our sample, not even for high-consumption households.

An important qualification of our study is its focus on eco-electricity customers: As these households are likely to have chosen an eco-electricity provider for environmental reasons, these households may be more likely to restrain their consumption voluntarily (Kotchen and Moore, 2008). This could be one reason why these households are not responding to our HER intervention. One positive conclusion from our null results is the fact that we do not find any evidence for the so-called boomerang effect which could have been expected from households that learn that their consumption is much lower compared to their peers, implying that these households may be prone to moral licensing. Making use of a model specification which is able to capture this exact channel, our results do not suggest that this mechanism is at work here.

Although or maybe precisely because our sample consists of eco-electricity customers, it seems surprising that we do not find any significant effects for high-consuming households. Compared to Andor et al. (2020), the average consumption levels in our sample are even a little higher and yet, we do not find any significant reductions as opposed to their study. Contrary to the voluntarily restraint as a reason to why our sampled households react less or not at all to the HER intervention, we might expect eco-electricity customers to be more responsive to our nudge (Costa and Kahn, 2013).

Especially from households who chose an eco-electricity provider for environmental reasons and learn they have a high consumption level compared to their neighbors, we would expect to see consumption reductions. Since we do not see any significant reductions for these relative high-consumption households either, our results indicate that eco-electricity households are not responsive to the social norm comparison at all. A possible explanation for the persisting null-effect for high-consumption households could be moral licensing where the purchase of green electricity makes a household feel legitimated to consume more than it's neighbors.

Our findings suggest that HERs are not suited to induce electricity savings with eco-electricity customers in Austria. As eco-electricity providers become more common, the customer pool may become more heterogeneous and not only consist of environmentalists or conservationists. Nevertheless, the fact that even high consumers in our sample do not respond to the HER intervention leaves us skeptical about the appropriateness of using HERs as a means to reduce energy savings in the first place. To conclude, our results stress the role of context-dependency of the efficacy and cost-effectiveness of HERs to reduce energy consumption and thus carbon emissions. Looking beyond the context-dependency of HERs, another point is the question of the effectiveness of the intervention in reducing emissions at a large scale if it did reduce electricity consumption levels. Even though EU member states like Austria are obliged to reduce final energy demand (EU, 2018), the limited climate impact is all the more true owing to Austria's membership in the ETS. Assuming that the ETS emissions cap is binding, then possible emissions reductions from HERs will ultimately release allowances and lower their price, allowing other emitters to buy them more cheaply. By way of the so-called waterbed effect (Perino, 2018), emissions savings in one sector will be offset by increases in another, rendering the greenhouse gas balance unaffected.

Appendix A

Figure A1: Social comparison element in HER (Translation of the original German Version).

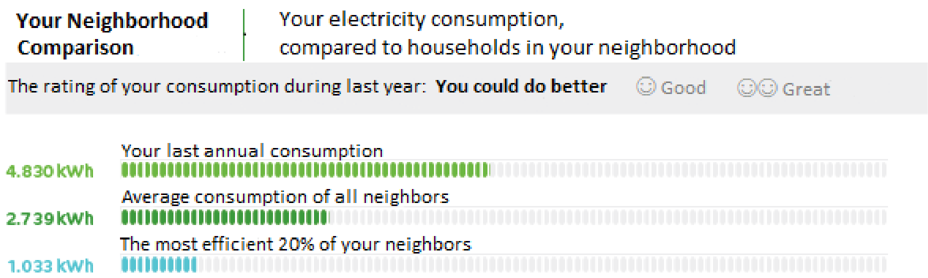


Figure A2: Number of mails received by treated households until end of study.

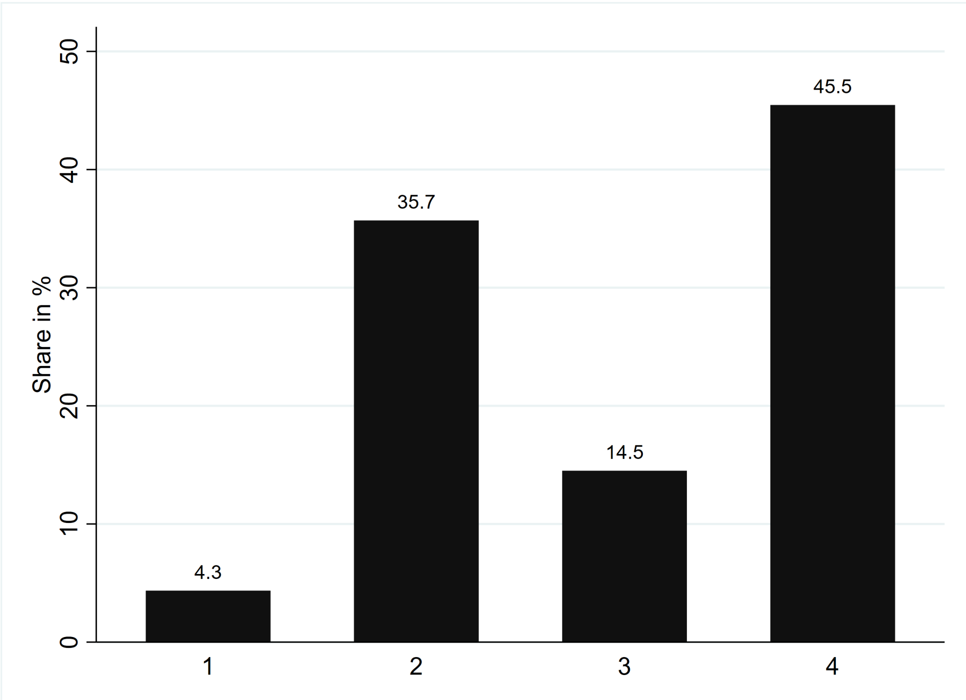


Table A1: Average treatment effect (ATE) on households' electricity consumption with sub-sample of households that received all 4 mails.

	Model 1		Model 2	
	Coeff.	s.e.	Coeff.	s.e.
T_{all4}	0.036	(0.528)	2.000*	(1.089)
$T_{all4} * Baseline_2$	–	–	-0.969	(1.374)
$T_{all4} * Baseline_3$	–	–	-2.546*	(1.411)
$T_{all4} * Baseline_4$	–	–	-4.320***	(1.469)
$T_{all4} * Baseline_5$	–	–	-2.016	(1.541)
$T_{all4} * Baseline_6$	–	–	-4.629***	(1.739)
$T_{all4} * Baseline_7$	–	–	-2.532	(1.735)
$T_{all4} * Baseline_8$	–	–	-2.817	(1.810)
$T_{all4} * Baseline_9$	–	–	-3.059	(2.115)
$T_{all4} * Baseline_{10}$	–	–	3.694	(2.822)
Constant	6.305	(7.636)	8.495	(6.923)
Baseline dummies	No		Yes	
Week controls	Yes		Yes	
R^2	0.0961		0.1169	
Observations	6,561		6,561	

Notes: Robust standard errors are in parentheses. *, and *** denotes significance at the 10 and 1 % level, respectively.

Figure A3: Effect of HER according to baseline consumption deciles for sub-sample of households that received all 4 mails.

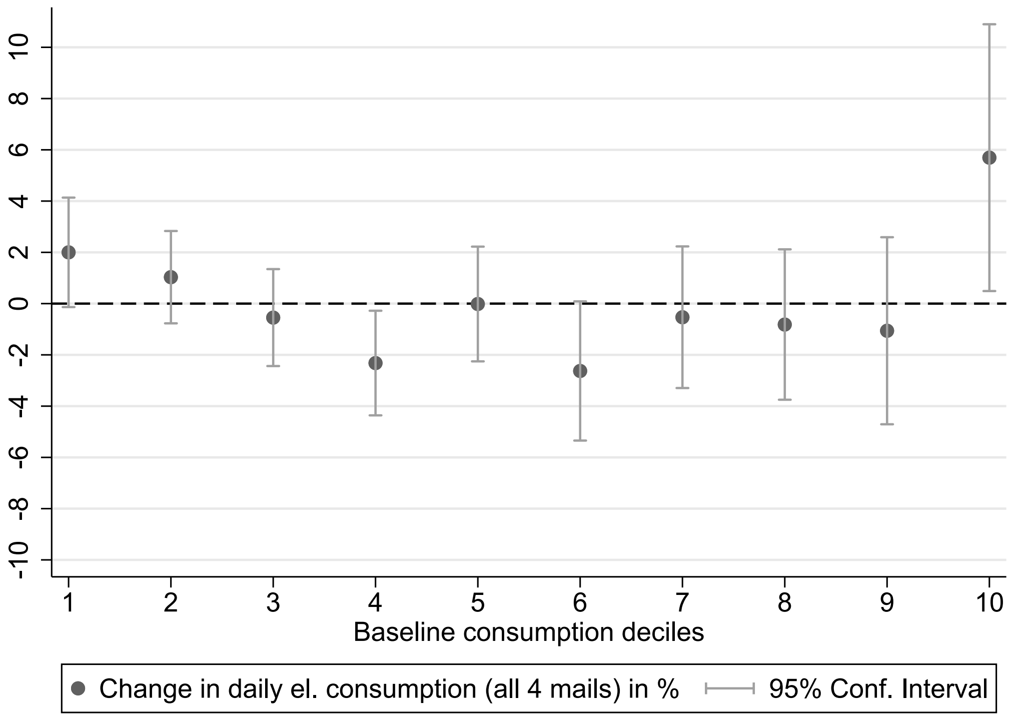


Figure A4: Effect of HER according to deviation deciles of mean zip code consumption from individual baseline consumption for sub-sample of households that received all 4 mails.

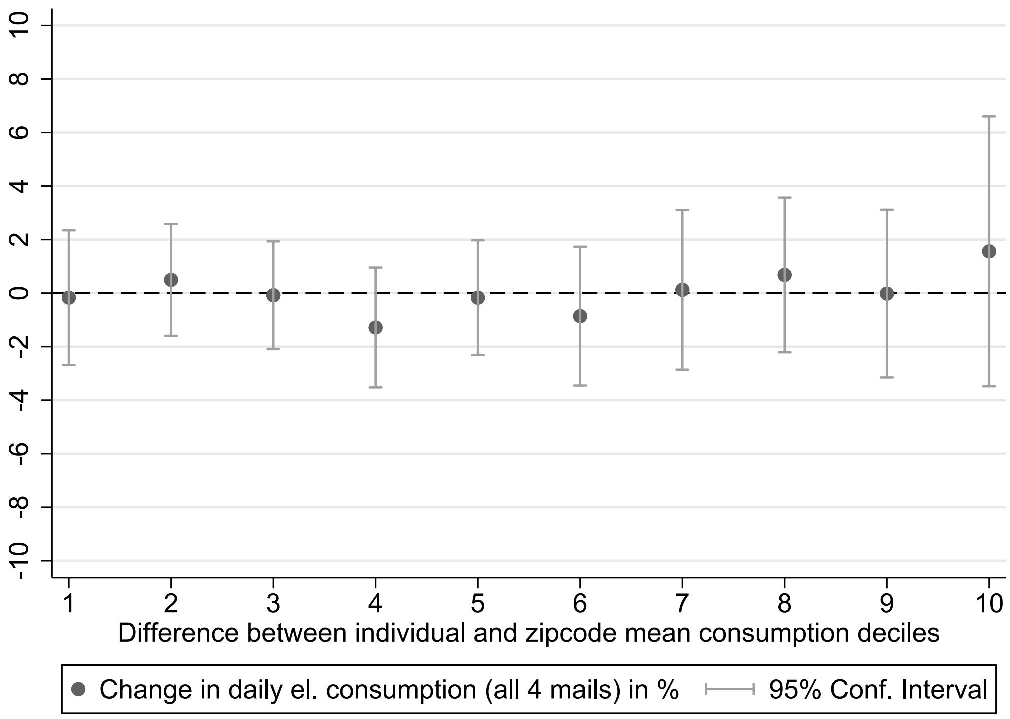


Table A2: Average treatment effect (ATE) on households' electricity consumption according to zip code deviation with sub-sample of households that received all 4 mails.

	Model 3	
	Coeff.	s.e.
T_{all4}	-0.168	(1.283)
$T_{all4} * Deviation_2$	0.662	(1.633)
$T_{all4} * Deviation_3$	0.088	(1.591)
$T_{all4} * Deviation_4$	-1.117	(1.678)
$T_{all4} * Deviation_5$	-0.002	(1.642)
$T_{all4} * Deviation_6$	-0.692	(1.815)
$T_{all4} * Deviation_7$	0.293	(1.945)
$T_{all4} * Deviation_8$	0.848	(1.907)
$T_{all4} * Deviation_9$	0.150	(2.011)
$T_{all4} * Deviation_{10}$	1.728	(2.819)
Constant	7.509	(6.345)
Deviation dummies	Yes	
Week controls	Yes	
R^2	0.1148	
Observations	6,561	

Notes: Robust standard errors are in parentheses.

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