Social norms and energy conservation beyond the US – A replication

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January 19, 2017

The seminal studies by Allcott (2011) and Allcott and Rogers (2014) show that social comparison-based home energy reports are a cost-effective non-price intervention to stimulate energy conservation in the US. This note presents findings from a replication of these studies in Germany. Based on a large scale randomized controlled trial, we find that the intervention only has a small effect on energy consumption. We additionally show that lower electricity consumption levels and carbon intensities make home energy reports cost-ineffective in virtually all other industrialized countries than the US.

JEL codes: D12, D83, L94, Q41.

Keywords: Social norms, energy demand, external validity, randomized field experiments, non-price interventions.

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Acknowledgements: We gratefully acknowledge financial support by the Stiftung Mercator. Furthermore, this work has been partly supported by the Collaborative Research Center "Statistical Modeling of Nonlinear Dynamic Processes" (SFB 823) of the German Research Foundation (DFG), within Project A3, "Dynamic Technology Modeling". Peters acknowledges the support of a special grant (Sondertatbestand) from the German Federal Ministry for Economic Affairs and Energy and the Ministry of Innovation, Science, and Research of the State of North Rhine-Westphalia. We thank Lukas Tomberg for excellent research assistance.

1. Introduction

A large literature has shown that social norms can affect individual choices in a variety of domains, such as water use (Ferraro et al. 2011, Ferraro and Price 2013) and charitable giving (Frey and Meier 2004, Shang and Croson 2009). The most prominent example is the social comparison-based home energy report that the company *Opower* mailed to more than six million households in the United States in order to reduce electricity consumption. Evaluations of *Opower's* home energy reports (HER) have documented considerable reductions in electricity consumption of 1.4-3.3% that are also persistent over time (Allcott 2011, Allcott and Rogers 2014).[1] Given the low intervention costs of HER, this evidence suggests that such non-price interventions can be a cost-effective policy instrument to combat climate change (Allcott and Mullainathan 2010).

In this note, we replicate the *Opower* social comparison-based HER intervention in Germany. Using data from a randomized natural field experiment among 11,620 households, we estimate the average treatment effect of HER on electricity consumption. Based on these estimates, we compare the intervention's cost-effectiveness in Germany to the *Opower* intervention. Furthermore, we gauge the cost-effectiveness of HER in other industrialized countries, assuming ranges of potential effect sizes documented in the literature so far.

While our paper does not question the internal validity of the Allcott (2011) and Allcott and Rogers (2014) findings, we test the external validity and transferability to other contexts. A number of reasons suggest the effectiveness of HER to differ across countries. First, evidence from psychology demonstrates that cultural backgrounds determine the extent to which individuals engage in social comparisons (Gibbons and Buunk 1999, Guimond et al. 2007). Second, energy conservation opportunities may be particularly large in the US, where the average annual electricity consumption of households amounts to more than 12,000 kWh, compared to a European average of around 4,000 kWh (WEC 2016). Third, the greenhouse gas mitigation potentials are co-determined by the carbon intensity of electricity generation that differs considerably between countries.

In fact, we find that the HER reduce electricity consumption in German households by 0.7% on average and thus less than half of the average reductions found in the *Opower* studies (Allcott 2011). Our results support the Allcott (2011) and Allcott and Rogers (2014) findings that HER

[1] Further studies that analyze *Opower* programs are Allcott (2015), Ayres et al. (2013) and Costa and Kahn (2013). In addition, there are numerous industry reports such as Ashby et al. (2012) and KEMA (2012)

are indeed a cost-effective policy tool for the US context. Yet, we show that this result is driven by high US residential electricity consumption along with a high carbon intensity of electricity generation and that HER are far from being cost-effective for countries other than the US.

The paper proceeds as follows. In the next section, we describe our HER intervention and compare it to the HER of the *Opower* project. In Section 3, we present findings on our intervention's effectiveness and perform cost-effectiveness calculations. Section 4 concludes.

2. Experimental Design to Replicate HER in Germany

2.1. Opower HER in the US

The *Opower* HER are letters that inform households about their electricity use based on three key components. First, the reports contain a social comparison module that contrasts the recipient's electricity consumption with the consumption of geographically and socio-economically similar households. Second, the reports provide electricity-saving tips. Third, the reports also visualize the evolution of monthly electricity consumption in the previous 12 months.

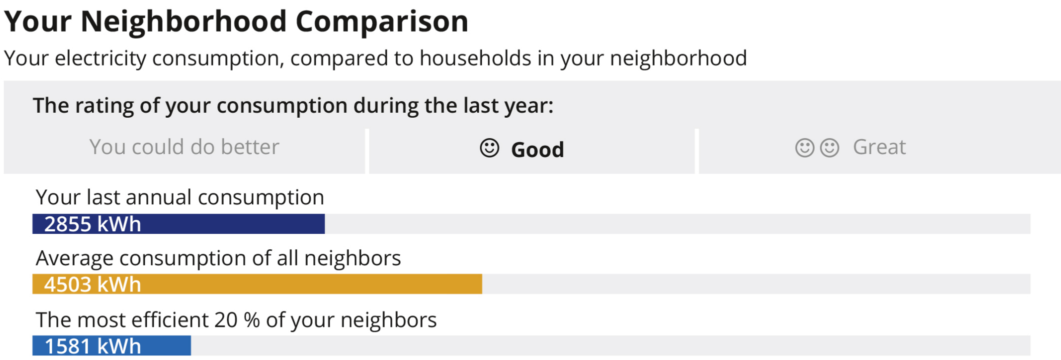
Opower sent HERs to customers of various electricity providers in the US, using monthly, bimonthly and quarterly frequencies. According to Allcott (2011), the estimated reductions in total electricity consumption range between 1.4 and 3.3%.

While quarterly reports have lower effect sizes than monthly reports, their performance in terms of cost-effectiveness is better due to lower printing and mailing cost. Furthermore, for a subset of three electricity providers, Allcott and Rogers (2014) show that reductions in electricity consumption persist beyond the HER treatment, but attenuate by around 15-20% per year.

2.2. The Treatment: HER in Germany

We designed the HER for our study in cooperation with the German energy consulting firm *Grünspar* and in a way that closely matches the *Opower* intervention. Households in the treatment group received four quarterly letters. Just as the *Opower* reports, our HER compare the household's consumption with that of its neighbors, as visualized in Figure 1, and provide tips on how to save energy. Two features of our HER were not contained in the *Opower* HER: our reports announce an individualized electricity consumption objective for each recipient household (10 percent less than the previous year) and additionally offer rebates for the purchase of energy efficient appliances that are available at the *Grünspar's* online shop. We expect this deviation to intensify the HER's effectiveness, but only slightly.

Figure 1: Social comparison element in HER (translation of the original German version)



Another distinction to the *Opower* HERs is that annual meter reading cycles in Germany do not allow for intra-year updates of the social comparison module. We expect such intra-year updates to amplify the energy conservation effect. To compensate for this deviation to the *Opower* HER, we simply repeat the social comparison based on the 2014-2015 annual electricity consumption in the first three reports. In addition, following a typical marketing approach, the fourth report contains "testimonials", i.e. exemplary descriptions of energy-saving actions implemented by households ("We have recently bought a new energy-efficient refrigerator that saves us around 60 EUR per year"). Table A2 provides a detailed comparison between our HER and the ones sent out by *Opower*. In addition, the four HER are comprehensively documented in the online appendix.

2.3. Experimental Design and Data

For the implementation of the study we cooperated with a medium-sized electricity provider located in Kassel, Germany, with 135,000 household customers. We randomized our HER intervention among those households that received their annual bill between November 2014 and April 2015. Our sample includes only those households that had been with the electricity provider for at least one year, so we can utilize data on baseline consumption. In addition, as in the *Opower* programs, only customers with exactly one meter per customer were included (Allcott 2011). In total, the trial was implemented in a study sample of 11,630 residential electricity consumers.

The randomization was stratified by households' baseline electricity use and the billing month.

Households in the treatment group received the four energy reports within one year, while households in the control group did not receive any report or communication other than the business-as-usual correspondence with the electricity provider. We sent the first report shortly after the household's annual meter reading.

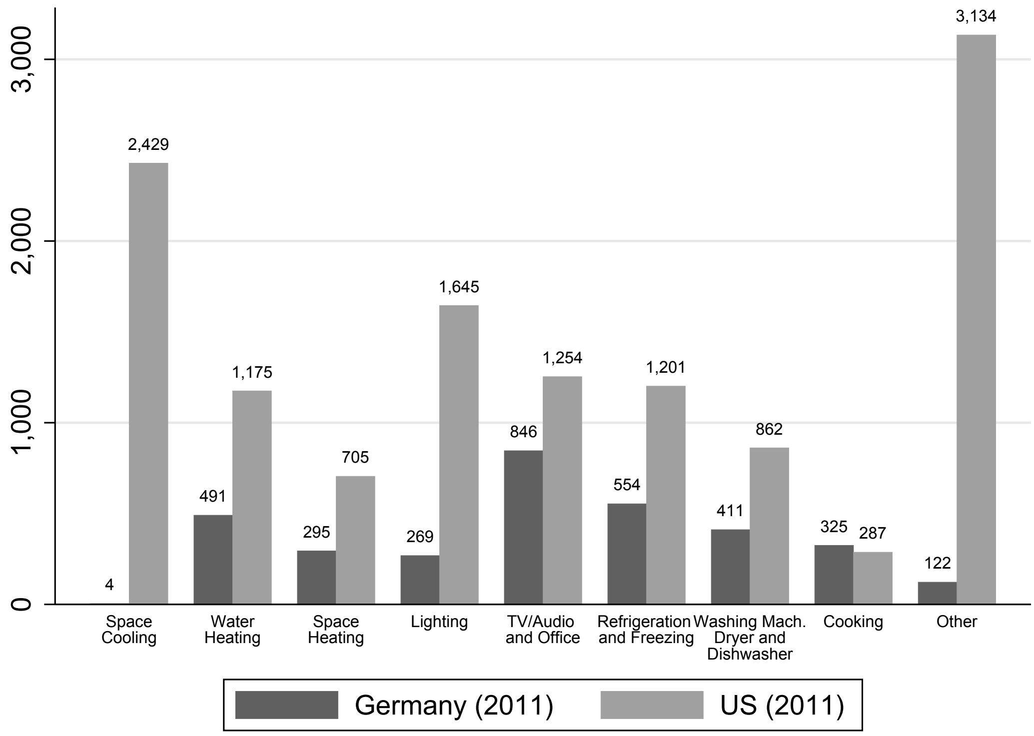
Table 1: Balance of baseline characteristics between treatment and control group

	Treatment Group	Control Group	Difference (Std. Error; p-Value)
Baseline consumption (2014), in kWh	2,265.9	2,263.8	2.07 (29.44; 0.94)
Baseline billing period length, in days	362.7	362.6	0.09 (0.12; 0.40)
Number of households	5,813	5,817	

Table 1 illustrates that baseline electricity consumption and billing period length are perfectly balanced across treatment and control group. Furthermore, the table shows that households in our German sample consume on average 2,300 kWh per year far less than the 12,000 kWh consumed by the average US American household (WEC 2016). Figure 2 disaggregates the electricity consumption by energy service for German and US households. US households consume at least twice the electricity of German households in every domain except for cooking. In particular, space cooling is virtually absent in Germany, also owing to different climatic conditions, but accounts for more than 2.000 kWh in the US.

Next, we examine the representativeness of our study region compared to the rest of Germany, using the *microm* dataset that offers socio-demographic variables at the regional zip code level. We find that our sample provides a fair representation in terms of key socio-demographic variables, such as percentage of retirees, unemployment rate, purchasing power, and non-German citizenship. Yet, our study's target area, Kassel and its surrounding suburbs, is more densely populated than the German average. Households are typically smaller in such urban settings, which partly explains the electricity consumption of study participants that is lower than the German average of around 3,300 kWh per year.

Figure 2: Composition of electricity consumption, USA vs. Germany



Note: US data is based on the most recent domestic electricity consumptions data from 2011, as documented in eia (2013). For Germany, we construct the same consumption categories for the year 2011 using data documented in BDEW (2016), UBA (2011) and Destatis (2015).

3. Results

3.1. Treatment Effects

To determine the Average Treatment Effect of the HER on the electricity consumption, we estimate the following differences-in-differences regression model:

$$\Delta Y_i = \alpha + \delta T_i + \epsilon_i \tag{1}$$

where ΔY_i corresponds to the change in the annual electricity consumption before (2014) and after the intervention (2015) for household i, T_i is the treatment dummy variable that equals unity for households that received the HER and ϵ_i designates an idiosyncratic error term.
To account for different billing period lengths, we normalize annual electricity consumption to 365 days. Following Allcott (2011), we divide it by the average post-period control group consumption, so that the average treatment effect identified by δ expresses average electricity

savings as a percentage of average consumption levels.

Table 2 presents the results and shows that the average HER treatment effect is a 0.7% reduction and statistically significant at the 10 percent level. This translates into an absolute average electricity reduction of around 16 kWh per year or 0.04 kWh per day, which is equivalent to turning off a 30 Watt light bulb for some 90 minutes every day. Moreover, the last column of Table 2 illustrates that we can exclude average reductions in electricity consumption greater than around 1.5% with 95% confidence.

Compared to the US, our estimate of a 0.7% reduction is substantially smaller. Because of the large differences in average consumption levels, absolute electricity savings diverge even more. The Allcott (2011) treatment effect for quarterly reports of a 1.7% reduction translates into absolute savings of 191 kWh per year (0.52 kWh per day), an effect size that is 13 times larger than what we observe for our sample.

Table 2: Average Treatment Effect on household's electricity consumption

	Estimates	Standard errors	95% Confidence Intervals
Constant	-1.43	0.27	[-1.95 ; -0.90]
ATE	-0.72	0.38	[-1.47 ; 0.03]
Number of obs.	11,620		
R^2	0.008		
F-Statistic	45.54		

Outcome variable: change in a household's annual electricity consumption between the treatment and baseline period, divided by the average control group consumption in the Post period (both in kilowatt-hours).

3.2. Cost-effectiveness of HER in Germany

To determine the cost-effectiveness of the HER intervention, we follow Allcott (2011) and divide the annualized cost of the reports by the average amount of kilowatt-hours saved per year. With printing and mailing cost of around 1.1 US$ per report, our estimates imply intervention costs per saved kWh of around 0.27 US$, compared to only around 0.01-0.05 US$ that Allcott (2011) calculates for the US. Our assumptions about costs of the intervention are optimistic in the sense that they neglect administrative costs, which may additionally arise from a systematic implementation of HER.

As HER are a potential instrument to combat climate change the main cost-effectiveness indicator are the costs per ton of mitigated carbon dioxide (CO_2). In general, the CO_2 abatement potential of electricity conservation depends crucially on the electricity mix in the respective country. For example, power sectors relying on lignite or hard coal are much more carbon intense than those relying on hydropower. For the US and Germany, the CO_2-intensities are virtually on a par at around 0.5 kg per kWh (IEA 2015). Dividing the cost estimates of 0.01-0.05 US$ per kWh and 0.27 US$ per kWh for the US and Germany, respectively, by this CO_2-intensity, suggests that the costs per mitigated ton of CO_2 amount to 560 US$ in Germany and 25-105 US$ in the *Opower* sample in the US.

The usual yardstick to assess whether a climate change mitigation policy is worth being pursued are the social cost of carbon (Greenstone et al. 2013). Nordhaus (2014) estimates that the social cost of carbon in 2015 are 19 US$ per ton, while U.S. IAWG (2013) provide an estimate of 34 US$. Abatement costs of HER in Germany are much higher than both estimates. In contrast, social cost of carbon can indeed exceed the abatement cost of HER in the US.

3.3. Projected cost-effectiveness beyond Germany and the US

We now use three key parameters to gauge the potential cost-effectiveness of HER as a climate policy instrument in other countries: the treatment effect of HER on the recipients' electricity consumption, baseline electricity consumption levels, and the carbon intensity of the electricity mix.

While additional replication studies would be required to identify the exact magnitude of treatment effects in other countries, we use the full range of treatment effects that have been reported in the literature so far. Our effect size is the lower bound at 0.7%, while the highest effect measured in the *Opower* program is at 3.3% (Allcott 2011). Baseline electricity consumption levels and carbon intensities, in contrast, are available from official data sets for industrialized countries. For simplicity, we assume printing and mailing cost to be at 1 US$ per letter in all countries.

For a set of other industrializes countries, Table 3 illustrates that for a given effect size HER are considerably less cost-effective than in the US, owing to the lower consumption levels and carbon intensities. Australia is the only country that reaches comparable CO_2 abatement costs, since both consumption levels and carbon intensities are high. While in Norway costs per kWh saved are low, electricity is generated almost without carbon emissions and thus CO_2 abatement costs are exorbitantly high. Our estimates suggest that no European country reaches CO_2 abatement cost that would justify using HER as a policy instrument to combat climate change when social carbon cost of 19-34 US$ are taken as a yardstick (see Section 3.2).

In Column 6 of Table 3 we present an indicator that summarizes HER's cost-effectiveness potential by country: the CO_2 abatement costs relative to the US. For example, holding the effect size constant, HER would induce abatement costs in Germany that are 3.7 times as high as in the US. In other words, to reach the same abatement cost level as in the *Opower* study (estimated average effect size of 1.7% for quarterly reports), the effect size of HER in Germany would have to be 6.3% (1.7%*3.7). This indicator is exclusively driven by the country's baseline electricity consumption level and the carbon intensity of its electricity mix. It can be seen that for countries such as France, Sweden and Norway it is virtually impossible that HER become a cost-effective climate policy intervention.

Table 3: International comparison of cost-effectiveness potentials for HER interventions

Country	Average Electricity Consumption in kWh	Cost in Cent / kWh	CO_2 Emissions in g / kWh	Cost in $ / t CO_2	CO_2 Abatement Cost relative to US
United States	12,293	1.0 – 4.6	489	20 – 95	1
European Union	3,943	3.1 – 14.5	337	91 – 430	4.5
Germany	3,304	3.7 – 17.3	486	75 – 356	3.7
France	5,859	2.1 – 9.8	64	323 – 1,524	16.0
Norway	16,297	0.7 – 3.5	8	930 – 4,383	46.0
Sweden	8,025	1.5 – 7.1	13	1,162 – 5,477	57.6
United Kingdom	4,145	2.9 – 13.8	459	64 – 300	3.2
Spain	4,040	3.0 – 14.1	247	121 – 573	6.0
Poland	1,935	6.3 – 29.5	769	81 – 384	4.0
Japan	5,434	2.2 – 10.5	572	39 – 184	1.9
South Korea	3,489	3.5 – 16.4	536	65 – 306	3.2
Australia	6,959	1.7 – 8.2	798	22 – 103	1.1

Note: Our calculations assume printing and mailing cost of one dollar per report, four reports per year and average electricity reductions of 0.7-3.3%. Average electricity consumption and CO_2 intensities of electricity generation correspond to the most recent values (for 2013) , as documented in WEC (2016) and IEA (2015), respectively.

So far, we have only considered electricity savings and thus CO_2 mitigation in the year of the treatment. As outlined in Section 2.1, Allcott and Rogers (2014) observe for the US that even after the HER intervention has ended, households continue to exhibit lower consumption levels than before. To calculate the HER abatement costs under an optimistic persistency scenario, we assume that effect sizes attenuate linearly by 15-20% per annum (Allcott and Rogers 2014) and set discount rates to zero. Even under such favorable assumptions, HER would never be cost-effective in France, Norway, Sweden, and Spain (Table A3 in the appendix). For the remaining European countries, as well as Japan and South Korea, only effect sizes close to the maximum of 3.3% can make HER cost-effective.

4. Conclusion

This paper has replicated the *Opower* social comparison-based home energy report (HER) intervention in Germany and scrutinized their potential as a climate policy instrument in a wide range of industrialized countries. Our estimates imply only modest average reductions in electricity consumption of 0.7%, less than half of what was observed in the US. A plethora of factors may explain why HER are not as effective in Germany as in the US. For example, cultural predispositions to respond to social comparisons may be less strong for German households, annual metering cycles (compared to monthly or quarterly metering in the US) may make HER less informative, and not least both behavioral and technical energy efficiency at the baseline might be higher in Germany.

While we cannot distinguish those mechanisms empirically, we can confidently reject that HER are a cost-effective policy instrument to curb carbon emissions in Germany. This finding is not only driven by a smaller effect size, but also by substantially lower electricity consumption levels of German households and would even hold true if we underestimated the treatment effect of HER by far. For other industrialized countries, low carbon intensities of electricity generation can additionally deteriorate the cost-effectiveness of HER, compared to the US. Indeed, we provide strong evidence that even under favourable assumptions on effect sizes and their persistency lower electricity consumption levels and carbon intensities make HER cost-ineffective in virtually all industrialized countries beyond the US.

A. Appendix

Table A1: Comparison of zip code characteristics between the study population and German averages

	Estimation sample	Germany
Population density, in persons per km^2	1.879	224
Percentage of retirees	23,5%	20,5%
Unemployment rate	6,8%	6,6%
Purchasing power per person, in 1000 EUR	22,0	21,3
Percentage of foreign household heads	7,0%	7,5%

Source: microm (2015).

Table A2: Comparison of HER Elements

	Our report	*Opower* (Allcott 2011)	Would we expect the differences to increase the effectiveness of our report?
Common elements			
Social (Neighborhood) Comparison	x	x	·
Electricity Consumption Feedback	x	x	·
Electricity Saving Tips	x	x	·
Diverging elements			
Possibility to get updated social comparisons and more energy saving tips via an app	x		+ (can trigger continuous engagement with the information from the letters)
Price discounts for energy efficient products in the online shop of the electricity provider	x		+/- (introduces incentives to buy energy efficient products/may crowd out intrinsic motivation)
Frequency of letters	Quarterly	Monthly - Quarterly	-
Update of information (comparison electricity consumption feedback)	Yearly	Monthly - Quarterly	-
Calculation of typical household sizes associated with electricity consumption	x		+ (additional intuitive comparison)
Testimonials (electricity saving actions that other households have implemented)	x		+
Communication of a 10% electricity saving goal within one year	x		+
Visualization of monthly electricity uses and comparison to last year's consumption		x	-

Table A3: Abatement Cost under Different Scenarios on the Persistency of Treatment Effects

	No persistence	15% reduction in effect size per year	20% reduction in effect size per year
Country	Cost in $ / t CO_2	Cost in $ / t CO_2	Cost in $ / t CO_2
United States	20 – 95	5 – 25	7 – 32
European Union	95 – 450	24 – 112	30 – 143
Germany	75 – 356	20 – 92	25 – 119
France	323 – 1,524	84 – 396	108 – 508
Norway	930 – 4,383	241 – 1,138	310 – 1,461
Sweden	1,162 – 5,477	302 – 1,423	387 – 1,826
United Kingdom	64 – 300	17 – 78	21 – 100
Spain	121 – 573	32 – 149	40 – 191
Poland	81 – 384	21 – 100	27 – 128
Japan	39 – 184	10 – 48	13 – 61
South Korea	65 – 306	17 – 79	22 – 102
Australia	22 – 103	6 – 27	7 – 34

Note: Following Allcott and Rogers (2014), the calculations in the Table assume linear attenuation rates of 15-20%. The cost-effectiveness calculations extrapolate electricity reductions until linear decay rates lead to zero reductions. Assumptions about annual electricity uses, carbon intensities of electricity generation and the range of effect sizes are as in Table 3.

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