Overcoming Salience Bias: How Real-Time Feedback Fosters Resource Conservation
- A Critical Discussion -

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(Prof. Dr. Manuel Frondel)

Author: Afra Otto

Contact to the author via Marcus Reinecke (programme coordinator MA Ethics – Economics, Law and Politics): marcus.reinecke@ruhr.uni-bochum.de

Summary

In their article *Overcoming Salience Bias: How Real-Time Feedback Fosters Resource Conservation* Tiefenbeck et al. (2018) show the enormous effect real-time feedback can have on resource consumption while performing one target behavior. They find an energy conservation of 22% which is stable over time. This paper summarizes the main approach and results. It illustrates two questionable points. First the recruitment of the study participants. Afterwards the possibility of spill-over effects and their influence on the overall energy conservation is discussed.

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1 Introduction

Even if it is currently taking a back seat in the face of the Covid-19-pandemic, according to the United Nations climate change is the defining issue of our time.[1] If the rising of global temperature should be limited to 1.5°C or 2°C, it will become unavoidable to reduce CO_2 emissions in various sectors, including the end-use sector. The IPCC report 2018 states that "[e]nergy-demand reductions are key and common features in 1.5 ℃ pathways, and they can be achieved by efficiency improvements and various specific demand-reduction measures." (IPCC 2018 p.136)

The effectiveness and efficiency of energy consumption reducing methods are thus also the subject of current research. One reason for the still insufficient energy savings in private households was investigated in 2015 by a group of scientists around Dr. Verena Tiefenbeck, meanwhile Professor for Digital Transformation at the Friedrich-Alexander Universität Erlangen-Nürnberg. The researchers expected a discrepancy between individual aspirations to environmental protection and the actual behavior. On reason, they guessed, is imperfect information of the actor. Imperfect information leads to a bias in favor of the salient. In their paper *Overcoming Salience Bias: How Real-Time Feedback Fosters Resource Conservation,* published by the journal *Management Science* in 2018, Tiefenbeck and her team present their field experiment's findings. By providing real-time feedback of the use of resources, they find a drastically reduction in water and energy consumption through showering by 22%. The result is significantly larger than those of studies examining other feedback methods. This essay summarizes the main approach and findings and provides a critical discussion of the real-time feedback's great success.

2 The Approach

2.1 Main Idea

In theory an agent needs complete information to take a decision according to her preferences. In reality, however, a situation with complete information is given rarely. This often leads to decision biases. Especially for resource use it holds, that some consequences of the consumption are more salient than others. Tiefenbeck et al. (2018) focus on the process of showering. While the benefits of showering are felt immediately, the negative implications of energy generation and emissions, so the costs, are elusive. This asymmetric visibility of benefits and costs tends to bias the decision in favor of the more salient. That means, because consumers do not see the costs of their action as clearly and as immediate as they feel the benefits, they use more resources as they would do in case of complete information.

This thesis is supported by various authors. Two online surveys by Attari et al. (2010 and 2014) confirm the clear discrepancy between estimated and actual consumption. Like Tiefenbeck et al. (2018), the authors find that consumers clearly underestimate the consumption of energy (Attari 2010) and water (Attari 2014). The bias towards the salience is also supported by Gatersleben et al. (2002). Even if people want to behave environmentally friendly, that often does not correlate with their actual energy use. One idea to overcome the gap between individuals' aspirations and their actual behavior are home energy reports. Different studies show the limited

[1] https://www.un.org/en/sections/issues-depth/climate-change/ (24.05.2020).

success of this intervention. Allcott and Rogers (2014) find that the effect intensifies with intervention's repetition. However, the overall effect remains neither big nor stable over time. Ferraro and Price (2013) make the same observation: The effectiveness of home reports wanes over time. A different method to inform consumers about their energy consumption are smart meters. They have the advantage of providing real-time feedback. In a large field experiment in Switzerland Degen et al. (2013) found evidence for energy savings between 3% - 5% due to smart meters. They gave real-time feedback about the household's aggregated energy use. Darby (2006) provides a review of studies on the effect of different feedback forms on individual behavior.[2] Her results support the thesis that home reports have less influence than direct feedback in form of smart meters. Neither of them is able to produce savings of more than 10%.

While the behavioral effects of home reports and smart meters are already investigated in different studies, Tiefenbeck et al. (2018) provide a systematical analysis of real-time feedback on resource consumption of one specific action while and where individuals engage in the targeted behavior. The large effect of 22% conservation is remarkably higher than previous studies have found for other forms of feedback.

2.2 Experimental Setup

If consumers had access to relevant information according the more elusive costs of an action while performing it, the attitude-behavior gap could be reduced.[3] Upon this idea, Tiefenbeck et al. (2018) created a field study in Switzerland. They provided real-time feedback on an individual's resource consumption while showering. They have chosen showering as an action because it is highly energy-intensive. According to Tiefenbeck et al. (2018) 14%-18% of the end user's energy consumption is generated by water heating. In addition, the consumer is able to directly adapt her behavior in response to the real-time feedback.[4] The IPCC's (2018) calculations show how indispensable it is to reduce this end user consumption if we want to keep the 1.5°C or 2°C pathway.

For the field experiment the treated households installed a smart shower meter[5] between shower hose and the hand-held showerhead. The smart meter shows water use in tenths of liters, water temperature in degrees Celsius, energy consumption in kilowatt-hours and an energy efficiency rating.[6] All measurements are shown in real-time while showering for the *real-time condition* group. A second group, the *real-time plus past feedback* group gets equal information plus the total amount of water used in the previous shower. The idea is to test whether the comparison with other household members produces pressure which further lowers the consumption. The control group receives no information about resource consumption but only the current water temperature in degree Celsius. The data obtained was evaluated by Tiefenbeck et al. (2018). Due to the design of the smart meter showers, resource consumption *per shower* is the primary unit during the whole analysis. The smart shower meter records the data per shower in

[2] Written and uploaded at the Environmental Change Institute, University of Oxford. The review is not published in scientific journal.
[3] And with it the consumption of resources – and with this the energy demand.
[4] Keeping in mind that showering as an action is relatively well suited to save energy, seems to be important. Looking at cooking, for example, it seems to be more difficult to achieve savings without buying more efficient appliances.
[5] The model amphiro a1, https://www.amphiro.com/de/produkt/amphiro-a1-basic/
[6] In addition, a polar bear or a melting ice floe is shown, which shrinks while showering.

sequential order and tracks the duration of each shower. However, it cannot measure the time between showers or recognize different household's members.

2.3 Sample

The sample, Tiefenbeck et al. (2018) use for their field study includes 636 one- and two-person households from Switzerland. The researchers had access to data collected by these 636 household's smart meters. However only for 620 households all necessary additional data, collected by one pre- and one post-experimental survey, were available.[7] The three treatment groups are composed as follows: The *real-time feedback* group consists of 215, the *real-time plus past feedback* group of 212, and the *control* group consists of 209 households.

All households were gathered out of the participants of a previous electricity smart metering study by Degen et al. (2013). After finishing the first study, 700 households got the amphiro a1 smart meter as a gift and could afterwards voluntarily opt to share their data with researchers. Tiefenbeck et al. (2018) recognize that active opting for a study carries the risk of potential biases of self-selection. Therefore, they compared the subset of participating households with 3,989 corresponding households from the previous study by Degen et al. (2013). While the subset does not differ in its demographics from the previous study, it does differ from the average Swiss population. It is younger, more educated and significantly less environmentally friendly than the average. However, within the three treatment groups there are no significant differences that could bias the studies' results.

3 Results

The previous paragraph presented the main idea, the experimental setup and the sample Tiefenbeck et al. (2018) based their field study on. They want to prove if a smart shower meter is able to correct salience biases within the highly energy-intensive activity showering. So, their actual aim is to prove the suggested effect real-time feedback has on resource consumption. To illustrate a picture of the whole situation, the authors analyze the data obtained in three steps. First of all, they investigate the effect on energy and water consumption as a whole. Afterwards they focus on the margins by which the effects are driven. Finally, Tiefenbeck et al. (2018) examine whether the intervention only leads to behavioral effects or if it has an impact on awareness about resource use, as well.

3.1 Energy and Water Consumption

Tiefenbeck et al. (2018) first evaluate the overall effects of the behavior-specific real-time feedback. The smart shower meter data shows that, after a baseline period of 10 showers, the treated group's behavior differs remarkably from the control group's behavior. Tiefenbeck at al. (2018) notice that: "*energy used per shower is approximately 0.59kWh lower than in the control group and water use is 9.5 liters lower, amounting to a reduction of 22% both in energy and water consumption for showering.*" (p. 1464f)

To confirm the results formally, Tiefenbeck et al. (2018) estimate the model

$$y_{it} = \alpha_i + \beta_1 T_{1it} + \beta_2 T_{2it} + d_t + \epsilon_{it} \,, \tag{1}$$

[7] Like demographics, household income, environmental attitude or the affinity to quantify goal processes.

where y_{it} is the energy used by household i in shower t. The explanatory variables describing this dependent variable are individual fixed effects α_i for each household and a shower fixed effect d_t which captures time trends. T_{1it} and T_{2it} indicate to which treatment group the household belongs. They equal 0 during the baseline period of 10 showers and for household's belonging to the control group. Otherwise T_{1it} equals 1 if the household belongs to the *real-time feedback* and T_{2it} equals 1 if it belongs to the *real-time plus past feedback* group. The other indicator takes the value of 0 respectively. So, β_1 indicates the difference between the control group and the *real-time feedback* group. β_2 indicates the difference between the control group and the *real-time plus past feedback* group. Finally, y_{it} depends on the unobservable error term ϵ_{it}. With the help of further estimations, Tiefenbeck et al. (2018) prove the stability of the treatment effects, as well. It turns out to last from shower 11 on until the end of the study period.

The visible impression of a significant reduction of resource use while showering is confirmed by the estimates. Tiefenbeck et al. (2018) find that the treatment effect on energy use is not only very large for both treatment groups but also highly statistically significant. The effect found is much greater than in studies that analyze the effects of home energy reports or real-time feedback on aggregated consumption. In addition, Tiefenbeck et al. (2018) find out that "the full treatment effect is realized from the first time the treatment is active, and the intervention is stable over time." (p. 1466) Amazingly, the experimental conditions seem to have the same impact on energy consumption for both treatment groups.

In order to better understand how individuals adjusted their behavior the authors examine possible margins of adjustment. They find out that by far the largest saving comes from cutting the shower short. Participating households within the treatment groups cut down their showers by 51 seconds in average. The effects of adjustments of water flow rate, temperature, number of stops during the shower and total break time are minor. In addition, Tiefenbeck et al. (2018) show that the total number of showers taken was not influenced by the treatment.

3.2 Awareness about Resource Use

Finally, Tiefenbeck et al. (2018) analyze the participant's awareness of the own resource consumption. Due to the pre- and post-experimental survey data, the authors are able to investigate the relation between individually estimated water consumption and the actual use. The results are gained by the regression model

$$\tilde{y}_i = \beta_0 + \beta_1 y_i + \beta_2 T_{1i} + \beta_3 T_{2i} + \beta_4 T_{1i} \cdot y_i + \beta_5 T_{2i} \cdot y_i + \epsilon_i, \quad (2)$$

where $\tilde{y}_i$ is the household's estimated water use in litres per shower. The actual use is represented by y_i. T_{1i} and T_{2i} indicate to which treatment group the household belongs, again. Equally, the coefficient β indicates how the treatments group's water use differs from the control group, again.

Tiefenbeck et al. (2018) find statistically highly significant evidence for the thesis that before the intervention, individuals had a rather vague idea of the own water consumption. Even if the relationship between estimated and actual water use is positive, individuals highly underestimate their consumption during the baseline period. For both treatment groups, however, the gradient increased noticeably during the study period. Compared to the control group both increases are significantly. Tiefenbeck et al. (2018) conclude that: "in contrast to other studies providing more aggregate, lagged feedback, real-time feedback increases awareness of resource use. This shows that the feedback gets to the users and provides a necessary first step for the intervention to reduce salience bias." (p. 1469)

4 Critical Discussion

Tiefenbeck et al. (2018) succeed in showing an enormous effect of real-time feedback on a certain activity. The participating households reduced their resource consumption for target behavior by 22%. That is remarkably much more than studies on other forms of feedback could prove. The results are not only highly statistically significant but seem to be very convincing due to the great study design. However, there are minor points that possibly could be criticized. In the following, the recruitment of the study participants is critically examined. Afterwards, the possibility of spill-over effects to other domains will be discussed.

4.1 Recruitment of Households

The effect of real-time feedback in the moment of performing one certain action seems to be very large, according to the results Tiefenbeck et al. (2018) present. However, as always, the findings could possibly be biased for some reason. Due to the voluntary character of the field study program, the participating households are not chosen randomly. The sample Tiefenbeck at al. (2018) use for their field study is a subgroup of a field study performed by Degen et al. (2013). So, it is interesting to understand how Degen et al. (2013) gained their study participants, first: A number of potentially suitable customers of a Swiss energy supplier from Zurich were chosen by chance. They were invited by letter to opt in the field study. The actual participants were selected out of all interested households by chance. If possible, for each participating household the energy consumption of two neighbors was tracked, as well. These neighbors had the chance to opt out.

Tiefenbeck et al. (2018) gained their study participants out of the group of households opted in for the Degen et al. (2013) field study. 700 households received the smart shower meter. For the experiment by Tiefenbeck et al. (2018) the participants of the former study had the chance to opt in again. Therefore, the group of participating households is a self-selected subgroup of an already self-selected super-group. The possibility of independent control by the randomly added neighboring households is completely eliminated for Tiefenbeck et al. (2018). The researchers see the risk of biases through self-selection. They find out that the subgroup does not differ in its demographics from the super-group. However, it does differ from the average Swiss population. The sample is younger, more educated and significantly less environmentally friendly than the average population. Unfortunately, we do not know if the sample has a higher affinity to quantify goal progress, because this seems to have a significant impact on the possible effect by the smart shower meter.

Within their scientific work Tiefenbeck et al. (2018) expect positive relations between personal attitudes and conservation effects for: baseline use, environmental attitude and the affinity to quantify goal processes. These assumptions are not only confirmed in the analysis of the data obtained. Tiefenbeck et al. (2018) prove that other studies and scientific work support the following relationships, as well:

a) The more environmentally friendly, the greater the effect on conservation.

b) The higher the baseline use, the greater the effect on conservation.
c) The greater the affinity to quantify goal processes, the greater the effect on conservation.

These assumptions can have consequences according the sample Tiefenbeck et al. (2018) ground their argumentation on, however. As already described, the group of households examined is significantly less environmentally friendly than the Swiss average. The less environmentally friendly an individual is, the smaller the effect of the feedback will be. Accordingly, the overall effect in the Tiefenbeck et al. (2018) study is reduced by this bias of the test group in contrast to the average population. This effect of relation a) is quite obvious. It may however be possible that both other relations wrongly shift the effect upwards.

Since the sample is less environmentally friendly, it could be assumed that the efforts of resource saving have been less than in the average population, before starting the study. This could also have an impact on shower behavior. If resource protection plays a less important role, it could be assumed that an above-average amount of water is used per shower. This hypothesis is supported by an article published in the magazine Aqua&Gas[8] in 2015. Freiburghaus (2015) specify the average Swiss water consumption per shower for 2014 at 37 liters. The baseline within Tiefenbeck et al.'s (2018) data sample indicates the average water consumption with 44.8 liters per shower. These numbers suggest that the baseline within the examined group is larger than that within the average Swiss population. So, it can be assumed that within the sample, above average water is used per shower. Referring to other studies, Tiefenbeck et al. (2018) state that "households with high baseline use display a larger conservation effect when provided with feedback about their resource consumption." (p. 1469) Taking together these facts, because of assumption b) the selection effect seems to falsify the treatment effect upwards. This means that the observed effect could be greater than it would be without bias in the average population.

The same could hold for the affinity to quantify goal processes. It is conceivable that a group of people who volunteered twice to take part in smart meter studies has this property stronger than the average population has. However, this hypothesis remains a hypothesis and is not supported by evidence.[9] Assuming that the hypothesis is true, because of relationship c) the effect found would again be bigger than it would have been for the average population.

Summed up the explained assumptions would bias the result: a) downwards, b) upwards, c) upwards. It is therefore not unlikely that the found effect of 22% savings actually is biased and does not correspond to the effect that the treatment would have shown outside the sample. This expectation is supported by a further study by Tiefenbeck et al. from 2019. Here the same smart shower meters are installed in six Swiss hotels. Of course, hotel guests do not represent the average population, as well. However, a different group of participants can be reached compared to the former field experiment. In addition, the opting in is avoided. It is also excluded that the participants are already sensitized to the topic by participating in further studies, as was the case in 2018. All in all, it can be assumed that the 2019 study will at least not be biased by the same

[8] This is the official publication organ of the Swiss Association for Gas and Water Technology SVGW and the Association of Swiss Waste Water and Water Protection Experts VSA.
[9] Unfortunately, I could not find any figures on the affinity to quantify goal processes for the average Swiss population.

reasons as the 2018 study. In fact, it turns out that with 11.4% reduction in energy use (Tiefenbeck et al. 2019) the effect is much smaller than it was in the previous study from 2018.

Under these circumstances, it might even be questionable whether real-time feedback is actually much more effective than other forms of feedback described above. Within a meta-review[10] Ehrhardt-Martinez et al. (2010) investigate 57 primary research studies on a variety of different feedback technologies. Summed up Ehrhardt-Martinez et al. (2010) found out that "since 1995 most studies across our international sample have documented average household savings of 4 to 12%, with savings a little lower in the U.S." (p.85) At 10.5%, the average energy savings for all types of feedback are higher in Western Europe than in the United States (7.4%). Darby's (2006) review showed slightly smaller findings with up to 10% savings. Against this background, Tiefenbeck et al.'s (2019) results and thus the real-time feedback no longer seems to be outstanding. Of course, real-time feedback is still very successful compared to other forms of feedback, but the position of the lone leader that the 2018 study suggests appears questionable in these circumstances.[11]

Not only this fact suggests that further research results are required before the role of real-time feedback can be assessed. The clear difference in the Tiefenbeck et al.'s study results from 2018 (22% energy savings) and 2019 (11.4% energy savings) also suggests that the results are still biased somehow. The results already clearly do show that the real-time feedback's success is great. Ultimately, however, further research is necessary to assess the method's actual effect.

4.2 Does Moral Licensing Endanger the Net Effect?

With their field experiment Tiefenbeck et al. (2018) succeed in showing that "real-time feedback on a specific activity (showering) reduced the resource consumption of that target behavior by roughly 22%." (p.1460) As described above, the results highly exaggerate former studies which evaluated smart home reports or aggregated smart meter feedback. Tiefenbeck et al. (2018) expect the overcoming of salience biases to be a reason for this great success. The more elusive costs of resource consumption become more salient through the smart shower meter. On this basis, individuals are able to make less biased decisions about their behavior and act more in line with their own preferences. Tiefenbeck et al. (2018) translate the 22% reduction in energy consumption when showering into a 5% reduction in total energy consumption. That would also mean a good success in terms of total energy consumption. However, this step could possibly be questioned.

Three years earlier, in 2013, Tiefenbeck et al. published another study based on a field experiment. Unlike in the 2018 study, they do not focus on one single target behavior. Instead they aim to "investigate [...] whether positive or perverse side effects dominate by exemplifying the impact

[10] Designed for the American Council for an Energy-Efficient Economy (ACEEE). The ACEEE is a non-profit research organization dedicated to advancing energy efficiency as a means of promoting economic prosperity, energy security, and environmental protection. Not published, again.

[11] Like the review by Darby (2006) on page 5, this review by Ehrhardt-Martinez et al. (2010) is not published, as well. Compared to Darby's (2006) numbers, Tiefenbeck et al.'s (2018) results appeared to be very large. Compared to Ehrhardt-Martinez et al.'s (2010) numbers and against the background described, Tiefenbeck et al.'s (2018) numbers do not seem that big anymore. In both cases, however, it is important to note that the comparative value was part of an unpublished review of other studies.

of a water conservation campaign on electricity consumption." (p.160) Finally they prove an increase in one domain (use of electricity) due to a saving in another domain (use of water). So, while households engage in saving water they increase their use of electricity. The saving of water was triggered by weekly home reports on the household's water consumption. The treated group reduced its water use by 6% compared to the control group. This size lies within the expected range for this intervention method and means an energy saving of 0.5kWh/person/day. In the same time electricity consumption in this group increased by 5.6% which means 0.89kWh/person/day. Tiefenbeck et al. (2013) conclude that "the energy saved by reduced (hot) water consumption was offset by the increased electricity consumption by nearly a factor of two." (p.169) Now it is questionable if this negative spill-over could have been found in the smart shower meter study from 2018 as well. In this case, the described effect of a 5% reduction in total energy consumption would be misleading.

In order to get an idea of whether this effect could also have occurred in the 2018 study, it is interesting to consider the underlying psychological mechanism. Tiefenbeck et al. (2013) expect moral licensing to be responsible for the negative spill-over. Other authors deal with the concept of moral licensing as well. Dütschke et al. (2008) precisely define the psychological theory of moral licensing. The authors sum moral licensing up to a feeling of being permitted to perform immoral or problematic because of previous good deeds in one domain. They see moral licensing as one trigger for rebound effects. Such effects are proven by many different studies. In a recent article, Harding and Rapson (2019) show that household energy consumption increases after the introduction of a carbon offset program. Because of the environmentally advantageous action the household feels permitted to act environmentally disadvantageous afterwards. A similar case of moral licensing was discovered by Jacobsen et al. (2012). After registering for a green electricity program, electricity consumption rose by 2.5%. Aydin et al. (2017) examine heating behavior in the Netherlands and find rebound effects between 27% and 41% through more efficient apartments.

All of these studies show that an environmentally friendly act can give the individual the feeling to be permitted to carry out an environmentally harmful act afterwards. Tiefenbeck et al. (2013) now also have proven that the negative effects can spill over to other areas than the examined ones. Thøgersen (1999) has shown the same. His investigation of waste separation behavior in Denmark shows behavior that corresponds with the principle of moral licensing. He finds out that "Performing an environmentally friendly behavior, such as recycling, seem to have a negative impact (spill-over effect) on the feeling of obligation to do other things." (Thøgersen 1999 p.74) However, he also found that the opposite could be possible. Elsewhere, Thøgersen (1999) proves that environmentally friendly behavior in one situation can trigger a more environmentally friendly decision in a later situation. Such results show how important it can be to collect other consumption data in order to achieve meaningful results in questions of environmentally friendly behavior.

For Tiefenbeck et al.'s study from 2018, it remains unclear whether and which spill-over effects have occurred, because no further consumption data was collected. As described previously, the target unit during the entire examination is "per shower". Energy consumption has broken down to the individual shower, as well. All statements about total energy consumption are therefore purely arithmetical. It would be very interesting to compare the results with the actual energy consumption.[12] If the calculations are correct and no spill-over effects occur, total energy consumption would have to decrease by approximately 5% compared to a control group. This effect should be stable over time. If the development differs from the calculated results, spill-over effects could be one reason. If consumption drops even more, positive spill-over effects could be responsible. If it drops less or rises, it could be due to negative spill-over effects. As the 2013 study has shown that negative spill-over effects can occur exactly for the area of water savings and electricity consumption, it makes sense to take this uncertainty into account in the study design.

5 Conclusion

Tiefenbeck et al (2018) impressively demonstrate the effectiveness of real-time feedback to save resources. They derive their results from their field study which is built up convincingly. The findings are consistent with the results provided by other authors, in principle. However, the effect found exaggerates former findings by far in magnitude. The authors show that the use of energy can be reduced by 22% due to real-time feedback on resource consumption while showering. This essay provided a critical discussion of their findings. First of all, the recruitment and the associated composition of the study participants were discussed. Due to the Tiefenbeck et al (2018) studies' voluntary character and the special recruitment procedure, the participating households do not represent the average Swiss population. The discussion shows that the selection effect might falsify the treatment effect. This impression is supported by the results of a follow-up study from 2019, which comes to a significantly different result with an energy saving of 11.4%. Further research into real-time feedback is necessary to assess the treatment's actual effect.

Furthermore, the discussion dealt with possible spill-over effects. Many scientific articles prove that environmentally advantageous actions may lead to environmentally harmful behavior, afterwards. One possible explanation for this effect is provided by the concept of moral licensing. In a 2013 study, Tiefenbeck herself provided evidence that the effects possibly also spill over to different than the target areas. As no overall consumption data was collected by Tiefenbeck et al. (2018) it might therefore be possible that the assumed effect of 5% household's energy conservation is biased. For further research it could therefore be interesting to consider the possibility of spill-over effects when designing a field study. Only then it is possible to find out if the results found here might be biases by positive or negative spill-over effects.

Finally, it can be said that further research on the promising topic of real-time feedback is quite important. Despite possible biases shown, real-time feedback remains a very effective (maybe the most effective) method to reduce the private consumption of resources. And it was stated at the beginning that this reduction in end-user consumption is essential in fighting global warming.

[12] Of course, this comparison is not easy out of multiple reasons like different target units or the availability of data. For a defined study-period, it could however be possible to compare the development of actual energy consumption before and after treatment with a control group. Perhaps even the study design from Tiefenbeck 2013 could be used with the smart meter as feedback method. Due to the setting in a multifamily residence the researchers were able to collect data on daily water and weekly electricity consumption of 154 apartments. This setting enables a great insight into the relationship between water saving and actual electricity consumption.

6 References

Allcott, H. & Rogers, T. (2014). The Short-Run and Long-Run Effects of Behavioral Interventions: Experimental Evidence from Energy Conservation. In: *American Economic Review*, 104(10), pp. 3003–3037. https://doi.org/10.1257/aer.104.10.3003

Attari, S. Z. (2014). Perceptions of water use. In: *Proceedings of the National Academy of Sciences*, 111(14), pp. 5129–5134. https://doi.org/10.1073/pnas.1316402111

Attari, S. Z., DeKay, M. L., Davidson, C. I. & Bruine de Bruin, W. (2010). Public perceptions of energy consumption and savings. In: *Proceedings of the National Academy of Sciences*, 107(37), pp. 16054–16059. https://doi.org/10.1073/pnas.1001509107

Aydin, E., Kok, N. & Brounen, D. (2017). Energy efficiency and household behavior: the rebound effect in the residential sector. In: *The RAND Journal of Economics*, 48(3), pp. 749–782. https://doi.org/10.1111/1756-2171.12190

Darby, S. (2006). *The Effectiveness of Feedback on Energy Consumption; A Review for DEFRA of the Literature on Metering, Billing and Direct Displays*. http://copperalliance.org.uk/uploads/2018/02/smart-metering-report.pdf

Degen, K., Efferson, C., Frei, F., Goette, L. & Lalive, R. (2013). *Smart Metering, Beratung oder sozialer Vergleich: Was beeinflusst den Elektrizitätsverbrauch?* https://www.energie-nachrichten.info/file/Energie-Report/2013/2013-07/30702_ER_Smartgrid_ewz_B.pdf

Dütschke, E., Frondel, M., Schleich, J. & Vance, C. (2018). Moral Licensing—Another Source of Rebound? In: *Frontiers in Energy Research*, *6*, pp. 1–10. https://doi.org/10.3389/fenrg.2018.00038

Ehrhardt-Martinez, K., Donnelly, K. A. & Laitner, J. A. (2010). *Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities* (E105). https://www.aceee.org/sites/default/files/publications/researchreports/e105.pdf

Ferraro, P. J. & Price, M. K. (2013). Using Nonpecuniary Strategies to Influence Behavior: Evidence from a Large-Scale Field Experiment. In: *Review of Economics and Statistics*, 95(1), pp. 64–73. https://doi.org/10.1162/rest_a_00344

Freiburghaus, M. (2015). Wasserverbrauch: Sinkender Wasserabsatz im Schweizer Haushalt. In. *Aqua&Gas*, (3), pp. 72–79. http://wasserqualitaet.svgw.ch/fileadmin/resources/svgw/web/Aktuell-Actualite/WV_Verbracuh_pers.pdf

Gatersleben, B., Steg, L. & Vlek, C. (2002). Measurement and Determinants of Environmentally Significant Consumer Behavior. In: *Environment and Behavior*, 34(3), pp. 335–362. https://doi.org/10.1177/0013916502034003004

Harding, M. & Rapson, D. (2019). Does Absolution Promote Sin? A Conservationist's Dilemma. In. *Environmental and Resource Economics*, 73(3), pp. 923–955. https://doi.org/10.1007/s10640-018-0301-5

IPCC. (2018). *Global warming of 1.5°C*. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_Low_Res.pdf

Jacobsen, G., Kotchen, M. & Vandenbergh, M. (2012). The Behavioral Response to Voluntary Provision of an Environmental Public Good: Evidence from Residential Electricity Demand. In: *European Economic Review*, 56, pp. 946–960. https://doi.org/10.3386/w16608

Thøgersen, J. (1999). Spillover processes in the development of a sustainable consumption pattern. In: *Journal of Economic Psychology*, 20(1), pp. 53–81. https://doi.org/10.1016/s0167-4870(98)00043-9

Tiefenbeck, V., Goette, L., Degen, K., Tasic, V., Fleisch, E., Lalive, R. & Staake, T. (2018). Overcoming Salience Bias: How Real-Time Feedback Fosters Resource Conservation. In: *Management Science*, 64(3), pp. 1458–1476. https://doi.org/10.1287/mnsc.2016.2646

Tiefenbeck, V., Staake, T., Roth, K. & Sachs, O. (2013). For better or for worse? Empirical evidence of moral licensing in a behavioral energy conservation campaign. In. *Energy Policy*, 57, pp. 160–171. https://doi.org/10.1016/j.enpol.2013.01.021

Tiefenbeck, V., Wörner, A., Schöb, S., Fleisch, E. & Staake, T. (2018). Real-time feedback promotes energy conservation in the absence of volunteer selection bias and monetary incentives. In. *Nature Energy*, 4(1), pp. 35–41. https://doi.org/10.1038/s41560-018-0282-1

United Nations. (o. J.). *Climate Change*. https://www.un.org/en/sections/issues-depth/climate-change/