Bachelor of Science

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Towards sustainable homes: A qualitative approach investigating household energy consumption and conservation behaviour.

Bachelor Thesis

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Abstract

Decreasing energy consumption and simultaneously increasing energy conservation in the residential sector is one of the main aspirations of nowadays. In fact, almost one quarter of the total energy consumption worldwide can be traced back to domestic energy use. Therefore, this study aims at investigating peoples' household energy consumption and conservation behaviour, while also taking influential factors and potential solutions into account. The study consisted of three separate qualitative data collection methods. Firstly, a diary study was employed to explore peoples' energy consumption behaviour. Secondly, a semi-structured interview was used to examine energy conservation strategies and influential factors. Lastly, a focus group was conducted to deepen and validate findings. Results revealed high energy consumption tendencies with entertainment devices (eg. Mobile-phones, Laptops etc.) and kitchen devices. Furthermore, significant correlations between the demographic variable age and increased energy consumption tendencies were found. Additionally, results indicate that participants charging behaviour and generation of illumination comfort might be explainable by habit formation. As influential factors social environment, electricity bill- price level, time, mood, awareness, and knowledge were identified. To increase energy conservation in households a multidimensional approach is suggested in order to tackle as many influential factors as possible.

Keywords: energy consumption, energy conservation, behaviour, households

Introduction

In modern days, the idea of living a "sustainable" way of life has become a central theme to environmental issues. The raising awareness concerning the world's environmental condition has its origin in 1987, when the United Nations World Commission on Environment and Development, released their report "Our Common Future", also known as "Brundtland report". Central to this report, was the invention of the term "sustainable development", which was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their needs" (Imperatives, 1987). Even then, it was already evident that a change of thinking is required, as there is only a little time remaining for tackling fundamental issues such as climate change, desertification, deforestation, toxic waste, and species loss (Imperatives, 1987).

Along with the invention of the term "sustainability" and the raising awareness, it became acknowledged that the pronounced growth of the human population will pose a great threat for the earth's environmental condition as there are not sufficient resources to satisfy the increasing needs and standards of humankind (Pecl et al., 2017). The growing demand and the increasing consumption of natural resources consequently promotes a more and more human-mediated climate change (Pecl et al., 2017). For this reason, it has become one of the main goals worldwide to reduce energy consumption and emissions to encourage sustainable development and, in this way, act against the side effects resulting from human-mediated climate change (Wang, Han & Lu, 2016).

According to Bertoldi, Ricci, and de Almeida (2000), it is especially necessary to look beyond fields such as transportation and industry. The authors propose that households need to be addressed directly to effectively reduce CO2 emissions as well as inefficient energy use. In other words, focusing on household devices and users of them might be one of the best chances to actually accomplish notable energy savings (Bertoldi et al., 2000; Botero & Nan, 2018; Alsalemi et al., 2019). Within the Western world, increasing attempts are made to adapt the house building standards to sustainable development principles. Research has shown that the expenditure of energy needed for housing as well as house construction is tremendous. A study in Sweden illustrated that around one fourth of the total energy consumption can be traced back to domestic energy use (Hagbert & Femenias, 2015). Furthermore, the demand of energy for heating and cooling of houses to sustain thermal comfort is considered to have a major impact on the earth environmental condition (Horne & Hayles, 2008). To reduce this enormous consumption of energy, improvements have been made by integrating more and more renewable energy technologies (RE) in sustainable housing projects (Anon, 2002).

However, exclusively focusing on household devices, without taking consumer's behaviour into account, would be a serious mistake. Indeed, proper usage of innovative devices is one key point for achieving energy conservation (Herring, 2006). While existing literature frequently states that

through technological innovation, energy efficiency would be improved and therefore more energy could be saved, it often fails to take everything into account. In fact, research has demonstrated that addressing household energy behaviour is at least equally important as technological innovation (Sorrell, 2015; Hagbert & Femenias, 2015). Consequently, it is necessary to also look beyond technical solutions and directly focus on consumer behaviour. For this reason, the following study aims at investigating peoples' energy consumption and conservation behaviour in households.

Theoretical Framework

In recent years, the origin and causes of inefficient energy use and emissions have been more and more investigated. It has been concluded that domestic energy use accounts for nearly one quarter of the overall carbon emissions and 40 percent of the total energy use (Botero & Nan, 2018). Furthermore, several studies and surveys confirmed that occupant behaviour is one of the main factors responsible for inefficient energy consumption (Hu et al, 2017). In this regard, "occupant behaviour" refers to activities performed on a daily basis to satisfy basic needs such as turning on cooling and heating devices, switching on lights, and adapting the thermostat to satisfy thermal comfort (Hu et al, 2017). To reduce this high consumption and promote energy conservation in the residential sector, two steps are necessary. Firstly, further enhancing technological devices and secondly, taking the user's behaviour closely into account (Belaid, Bakaloglou & Roudbaud, 2018). While technological advances certainly improve energy efficiency, centering emphasis on people's behaviour seems more substantial, as it is the greatest influential factor in household energy consumption (Alsalemi et al., 2019).

Providing that focusing on people's behaviour might achieve promising effects, research already specified multiple factors, playing a role in energy consumption and conservation behaviour. Among those, were for example, knowledge, energy attitudes, energy behaviours, energy habits, and ownership of appliances (Pothitou, Hanna, & Chalvatzis, 2016; Attari, DeKay, Davidson, & De Bruin, 2010). Moreover, as stated by Wallis, Nachreiner and Matthies (2016), investigations further illustrated that also the variables age, income, and living space are crucial determining factors with regard to energy consumption and conservation behaviour.

Furthermore, the considerable influence of the variables knowledge and awareness was further promoted by literature. Research has shown that knowledge, as well as awareness, positively affect environmental personal norms, thus increasing energy conservation tendencies among individuals (Niamir, Iyanova, Filatova, Voinov, & Bressers, 2020). While people were generally provided with vital information on their energy use due to their electricity bills, research revealed that householders maintain misconceptions about their devices' power consumption. As an example, investigations demonstrated that some individuals even believe that the size of a device provides a solid indication on its energy consumption (Wang & Moriatry, 2017). A study by Attari and colleagues (2010) further

verified the formation of these misconceptions. Particularly, it was found that individuals not only have the inclination to either over – or under-estimate the power-consumption of devices, but it was also confirmed that people substantially underestimate their overall-energy consumption (Attari, DeKay, Davidson, & De Bruin, 2010).

Moreover, in current literature, the strong impact of habits on energy consumption and conservation behaviour is frequently discussed. By now, it is an established fact that many activities are performed habitually as they became part of our daily routine. Mainly elicited by contexts, these activities are performed unconsciously. Once consistency within these activities develops, habits are likely to be formed (Marechal, 2010). Once formed, it becomes extremely challenging to change them (Lee, Kang, Song, & Kang, 2020). As the formation of habits applies to many behavioural contexts, it is also applicable to energy consumption and conservation behaviour. Research indicates that considering the impact of habits is vital when discussing essential factors, influencing energy consumption and conservation behaviour (Marechal, 2010). Additionally, within several studies habits were observed as one of the major contributors of inefficient energy use (Lee et al., 2020).

However, these were not the only drivers identified in current research. Interestingly, peoples' environmental decision making is also, to a great extent, shaped by interactions with their social relations. In fact, a meta-analysis by Bamberg and Mösner (2007), revealed that not only peoples' personal norms but also their social norms positively influence their environmental behaviour tendencies. The positive impact of personal and social norms on household energy conservation behaviour is additionally promoted by further literature (Chen, Xu, & Day, 2017).

Overall, multiple factors were identified as influencing people’s energy consumption and conservation behaviour. The question rises what means can be employed to counterbalance these factors. A systematic review by Andor and Fels (2018), discussed the effect of social comparison on energy conservation behaviour. In that context, social comparison was introduced as the process of providing individuals with feedback about their energy consumption tendencies. This feedback is based on a comparison to a relatively comparable household. In that sense, social comparison aims to modify biased beliefs about one's energy consumption. A considerable number of studies were already conducted to test the proposed effect of social comparison on energy consumption behaviour. As a result, social comparison interventions were shown to significantly reduce household energy consumption by 1.2% up to 30% (Andor & Fels, 2018). Therefore, social comparison seems to be an effective intervention strategy for reducing energy consumption, especially when considering the influence, as mentioned earlier, of social norms on energy consumption behaviour.

Besides the social comparison strategy, studies demonstrated interesting results when tackling the factor knowledge. As stated by Pothitou and colleagues (2016), two studies revealed that through the integration of an online interactive information system, notable energy savings could be achieved. Aimed at increasing householders' knowledge by means of feedback, householders' energy consumption was reduced by 5% to 9%, compared to control groups (Pothitou et al., 2016). Hence,

enhancing peoples' knowledge of efficient energy use is another strategy, leading to the desired outcome, namely increasing household energy conservation.

Furthermore, a scientific review by Iweka, Shukla, and Yan (2019) addressed the effectiveness of prompts to offset undesired habits. Prompts can be used to counteract habits by reminding individuals to act more efficiently when dealing with electrical devices. Prompts can be illustrated in the shape of stickers, posters, and signs, etc. On the one hand, by reminding individuals to, for example, switch off unnecessary lights as well as only putting as much water as needed into the water boiler, etc., prompts seem to function effectively. On the other hand, the authors clarified that using prompts might only lead to a notable desired effect if the individual is also motivated to change habits (Iweka et al., 2019). Nevertheless, to counterbalance the factor habits, prompts might be a good first solution.

On the whole, research identified multiple factors affecting people's household energy consumption and conservation behaviour. Although a variety of studies focus on determining suitable intervention techniques for reducing household energy consumption, it still poses a great issue. Since multiple factors have to be taken into account when considering household energy consumption, there is probably no single fixed solution. However, literature indicates that by applying several existing intervention strategies at the same time, energy consumption could be decreased by approximately 20% (Iweka et al., 2019). However, in order to decrease energy consumption and increase energy conservation in households, further research is necessary. The present study aims to explore relevant factors that are depicted to influence energy consumption and conservation behaviour. Furthermore, this study tries to elucidate key points that may contribute to behavioural change. Thus, the present findings in this study may help to facilitate intervention research. Key factors identified in this study may serve as basis to induce re-structuring of energy consumption- and conservation behaviour. Ultimately, the topic of this thesis may be centred around what subjective perceived factors may contribute to the introduced theoretical framework. Consequently, the research question are as follows:

Research questions

Research question 1: Which household behaviours do people display that consume energy?
Research question 2: Which household behaviours do people display to conserve energy?
Research question 3: What are possible factors influencing peoples' energy conservation behaviour?
Research question 4: What could be done in order to increase energy conservation in households?

Methods

Design

The study consisted of three separate qualitative data collection methods. Firstly, a diary study was implemented to investigate participants' energy consumption behaviour within their households. Secondly, a semi-structured interview survey design was employed to further explore energy consumption and conservation behaviour of a different sample. Lastly, a focus group was conducted in order to validate the findings from the interview study.

Participants

All participants were recruited via convenience sampling and randomly assigned to one of these three strategies. During the selection process, care was taken to ensure that the sample is rich in diversity.

In the diary-study approach, twelve participants volunteered their time for the study. The ages ranged between 21-53, with a mean age of $M = 31.3\ 7$ ($SD = 10.85$). Moreover, out of 12 participants, seven were students and the additional five were employed. Although care was taken to ensure diversity, participants' gender was not equally distributed across the sample. In total, four males and eight females participated in the study (see appendix A1).

With regard to the interview study, nine people participated. Within this strategy, diversity in terms of age could not be implemented. The ages ranged from 20 to 24 years, with a mean age of $M = 21.77$, ($SD = 1.56$). Furthermore, the sample consisted of five female and four male participants. Additionally, all participants indicated to be students (see appendix A2).

In total, five male students participated in the focus group. Their ages ranged from 22 to 26. Thus, the mean age in years was $M = 23.8$ with a standard deviation of $SD = 1.48$ (see appendix A3).

Procedure & Materials

Before starting the data-collection process, ethical approval was requested and permitted by the ethical committee of the University of Twente. This had to be done in order to assure that the data collection was implemented according to ethical requirements. Once ethical approval was obtained, all recruited participants received an Email, in which the purpose and course of the research was explained. Prior to participation, participants filled out a short questionnaire concerning their demographic data. Depending on their assigned conditions, participants got additional instructions.

To begin with the diary study approach, participants received an E-mail containing the prefabricated diary questionnaire document (see Appendix B1), their participation number, informed consent **(**see appendix A4) and few additional explanatory information. Additionally, all explanatory information was included within the diary document. Moreover, participants received the instruction

to document their energy consumption behaviour for a five-day period (15.04.20-19.04.20). More specifically, participants filled out the diary-documents, in the evening, after completing most of their usual daily habits. To ensure this, each day the researcher sent out a reminder via WhatsApp at approximately 8 pm. After completing the diary study for five days, the participants had to send their documents back to the researchers. The material used in the diary study, was a pre-developed diary questionnaire, consisting of several tables and three follow-up questions (see Appendix B1). The diary document was developed for two main reasons. One the one hand to simplify the documentation process for participants and on the other hand to ensure a standardized evaluation process.
Each table, on the diary document, was intended to constitute a room, as for example: kitchen, bathroom, living room etc. Moreover, typical activities usually performed inside one of these rooms were displayed within these tables. To give an example, the activity “cooking” was thus included in the table representing the kitchen. Furthermore, at the end of each diary, participants answered three follow-up questions. These were constituted to get an idea about participants personal appraisal towards their amount energy consumption. Lastly, the diary document was developed for two main reasons. One the one hand to simplify the documentation process for participants and on the other hand to ensure a standardized evaluation process.

For the interview survey design, participants indicated their Skype ID, for an online interview. Afterwards, the researcher called the participant. The interviews lasted on average approximately 20 minutes. Every interview was recorded and transcribed. At the end of the data collection process, all online details of participants were removed in order to protect participants’ anonymity. Self-developed semi-structured interview questions were used (see Appendix B2), aimed at investigating participants' energy consumption and conservation behaviour. To be precise, participants were asked about frequently performed behaviours, resulting in energy consumption. Moreover, they were asked to explain and elaborate on their energy conservation techniques. Additionally, to get deeper insight into possible factors influencing participants energy conservation behaviour/strategies, questions concerning this were included as well.

Concerning the focus group, participants were invited via Email to join a collaborative Skype Call. During the skype call, the researcher stimulated a discussion about possible drivers of inefficient energy consumption as well as new energy conservation methods and strategies. The entire discussion was recorded, and main points were transcribed afterwards. To protect participants anonymity, all online details were deleted afterwards.

Results

Descriptive Statistics (RQ 1)

The first aim of this research was to investigate which household behaviours people display that consume energy. To answer this question data collected during the diary study will be considered.

Table 1. visualises participants' overall energy consumption per room as well as per activity in hours. To facilitate the representation of the data, all time specifications made by the participants were converted into hours. The data was gathered over a five-day period (15.04.2020-19.04.2020), and all-time specifications were summed-up and converted into one single score in hours.

The analysis demonstrated that participants spent most time, consuming energy inside their living/personal-rooms M = 40.97; (SD = 11.79) hours. On average participants spent M = 16.38; (SD= 9.91) hours on their laptops/computers, which is the highest score inside the variable "living/personal-room". Another score that stands out is displayed by the activity "using mobile-phone", M =14.31; (SD = 7.89). The lowest score is presented by the activity "using printer", where participants spent on average M = 0.07; (SD = 0.14) hours, printing documents. Concerning the activities/devices performed/used inside the variable "kitchen", participants dishwashers displayed the highest score with a running-time of M = 4.45; (SD = 3.54) hours. However, not every participant indicated to own a dishwasher. For this reason, also the activity "washing the dishes by hand" was included. On average participants spent M = 0.62; (SD = 0.60) hours washing their dishes by hand. "Cooking" is with a mean of M = 2.94; (SD = 1.69) hours, actually the activity by which participants spent the most time, consuming energy. The lowest score is demonstrated by the activity "using other devices", M = 0.08; (SD = 0.19) hours. To give an example, the activity "using other devices" includes the usage of devices such as microwaves, mixer etc. Lastly, participants spent on average M = 1.39; (SD = 0.72) hours inside their bathrooms, consuming recourses (mostly water), as well as using electrical devices. The activity "taking a shower" demonstrated the highest score with M = *0.*75; (SD = .41), whereas the activity "using hair styling devices", displays the lowest score M = .14; (SD = 0.20).

Table 1.
Descriptive statistics for household energy consumption per room and activity in hours.

Variable	Mean (SD)	Minimum	Maximum
Kitchen Total	8.46 (4.19)	3.10	14.10
Using dish-washer	4.45 (3.54)	0.00	9.50
Washing dishes by hand	0.62 (0.60)	0.00	2.30
Cooking	2.94 (1.69)	1.30	5.80
Water-boiling	0.27 (0.26)	0.00	0.80
Using toaster	0.12 (0.21)	0.00	1.51
Using other devices	0.08 (0.19)	0.00	0.70
Bathroom Total	1.39 (0.72)	0.50	3.40
Taking a shower	0.75 (0.41)	0.20	1.50
Washing the hands	0.48 (0.32)	0.10	1.40
Using hair styling devices	0.14 (0.20)	0.00	0.50
Living/personal-room Total	40.97 (11.79)	18.80	64.30
Watching television	6.09 (8.02)	0.00	26.00
Using laptop/computer	16.38 (9.91)	0.30	31.00
Using mobile-phone	14.31 (7.89)	1.90	27.00
Using game consoles	1.91 (4.48)	0.00	15.00
Using music system	2.23 (3.55)	0.00	10.00
Using printer	.07 (0.14)	0.00	0.50

Total N=12

Table 2. illustrates the duration in hours, which participants used to charge their electrical devises. All things considered, participants spent $M = 32.10$; ($SD = 15.79$) hours charging all their electrical devices. The highest score is displayed by the activity "charging mobile-phone", where participants spent on average $M = 20.14$; ($SD = 15.32$) hours charging their phones. Noteworthy is the fact that although participants used their laptops more/longer than their mobile phones (see table 1.), participants spent more time charging their mobile-phones. Thus, participants seem to have a different charging behavior when it comes to their laptops. This is demonstrated by the score of "charging

laptop" (*M* = 8.50; *SD* = 8.59) which is considerably smaller than the score of "charging mobile phone" (*M* = 20.14; *SD* = 15.32*)*.

Table 2.
Descriptive statistics for charging electrical devices in hours.

Variable	Mean (SD)	Minimum	Maximum
Charging devices total	32.10 (15.79)	6.00	61.00
Charging mobile-phone	20.14 (15.32)	3.60	43.00
Charging laptop	8.50 (8.59)	0.00	23.00
Charging other devices	2.45 (5.52)	0.00	18.00

Total N=12

Table 3. demonstrates participants lighting activities per room in hours. On average, participants spent *M* = 31.42; (*SD* = 27.18) hours illuminating their households. Most hours were expended for illuminating participants living/personal –room (*M* = 11.51; *SD* = 9.78). This result is also in line with participants energy consumption inside these rooms, as participants consumed most energy and therefore spent most time inside their living/personal-rooms (see table 1.). Moreover, the score of "lighting hall" (*M* = 4.04; *SD* = 8.15) seems to be remarkably high, if one presumes that participants probably did not spend that much time inside their halls.

Table 3.
Descriptive statistics for participants generation of illumination comfort in hours.

Variable	Mean (SD)	Minimum	Maximum
Lighting Total	31.42 (27.18)	4.50	98.00
Lighting kitchen	6.90 (6.91)	.10	20.00
Lighting bathroom	3.77 (3.32)	.40	11.00
Lighting living/personal room	11.51 (9.78)	.50	31.50
Lighting bedroom	5.17 (7.93)	.00	24.50
Lighting Hall	4.04 (8.15)	.00	25.00

Total N=12

Relations between consumption behaviours (RQ 1)

In a next step, potential associations between behaviours that consume energy were investigated. Therefore, the various consumption behaviours were cross correlated exploratively. Interestingly, some significant correlations between variables were observed, using spearman's correlation coefficient. This correlation coefficient was used in account of the small sample size (N = 12).

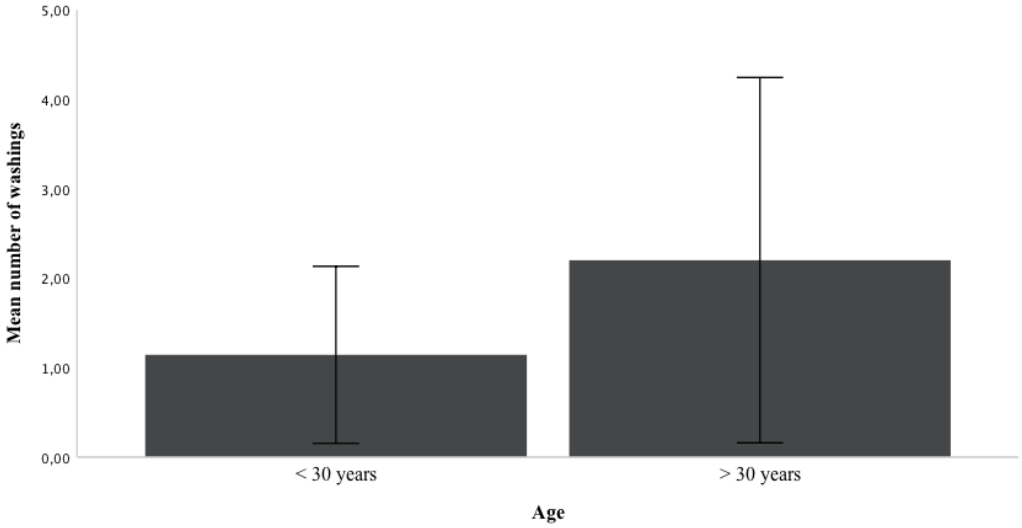
Within table C1. (see appendix) correlations of the total energy consumption per room are visualized. Results of the Spearman correlation indicated that there was a strong positive association between bathroom total and kitchen total (rs (10) = .608, p < .05). This means that the more time participants spent consuming energy inside the bathroom, the more time they spent consuming energy inside the kitchen.

Moreover, in table C4. (see appendix) correlations between activities performed inside the kitchen were demonstrated. The spearman correlation revealed that there was a strong positive significant correlation between water-boiling and participants age (rs (10) = .583, p < .05). Hence, the older participants were, the more frequently they used their water-boilers. Furthermore, activities performed inside the living room were correlated with each other (see appendix, table C5.). The analysis showed a strong significant negative correlation between the activities "using laptop/computer" and "watching television" (rs (10) = -.744, p < .05). This means that the more participants used their laptops/computers, the less time they spent watching television. In addition to that, a strong significant positive correlation between the activity "using game consoles" and participants gender was demonstrated (rs (10) = .807, p < .05). This implies that male participants used their game consoles considerably more frequently than female participants. Moreover, activities performed inside the bathroom were correlated as well (see appendix, table C6), revealing a strong significant positive association between the activity "using hair-styling devices" and participants age (rs (10) = .630, p < .05). Thus, the older participants were, the more often they used hair-styling devices. Lastly, participants characteristics were correlated with their lighting and charging behaviour (see appendix; table C3 and C2), however, no significant relationships were found.

Relations between consumption behaviours and demographics (RQ 1)

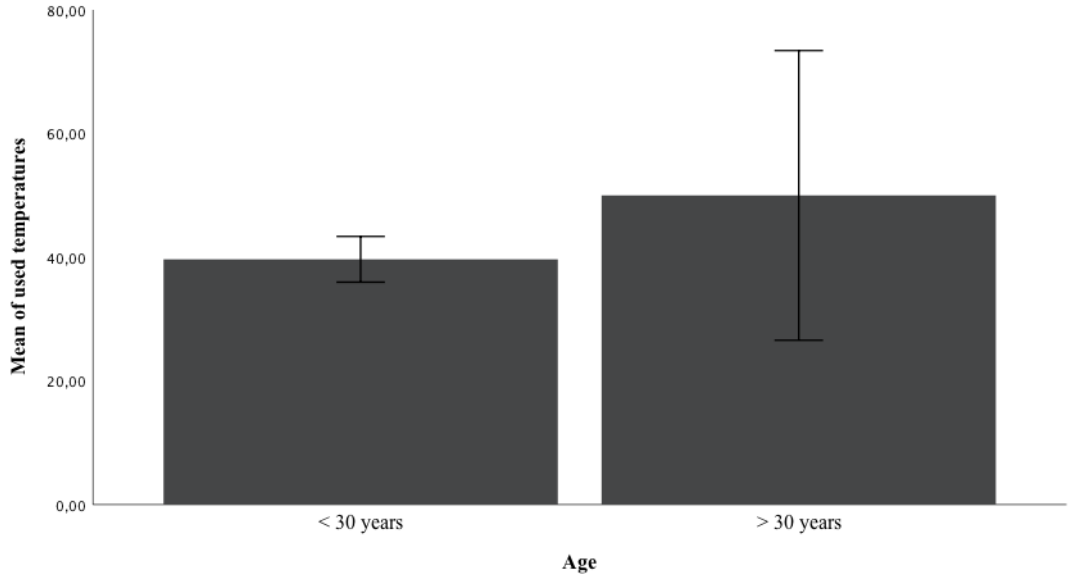
Since participants "washing-behaviour", was of interest as well, and indications of them were quite diverse, differences among the sample were illustrated by means of graphical illustrations (using histograms). Moreover, research indicated that "older" individuals not only tend to consume more energy but also their aspirations towards comfort was shown to increase with age (Belaid, 2016). Therefore, it was decided to use the demographic factor "age" as independent variable.

Figure 1. illustrates age differences for the activity “doing laundry – using washing-machine”, based on the number of washings. The variable age was coded as a nominal variable, consisting of two different age groups. Furthermore, both groups were about equal in size. The first bar represents participants under the age of 30 (< 30 years), while the second bar portrays participants older than 30 years (> 30 years). Moreover, the variable “Mean number of washings”, refers to the average number of washings. As stated in the figure caption, the included error bars represent 95% confidence intervals. As can be observed, there is an overlap between confidence intervals of the two groups. Thus, the histogram gives an indication that older individuals tend to do their laundry more frequently, however, as no significance level is included it cannot be stated with certainty.



Total N= 9
Figure 1. Histogram of the activity “doing laundry – using washing machine”, on the basis of participants age (error bars represent 95% confidence intervals).

Figure 2. visualises age difference for the activity “doing laundry-using washing machine”, on the basis of used temperatures. In this case as well, the variable age was coded as a nominal variable, representing two different age groups (<30 years and > 30 years). However, now it was of interest to analyse whether participants of an older age (> 30 years), tend to wash their laundry also on higher temperatures. The error bars represent 95% confidence intervals. It can be concluded that individuals > 30 years, probably have the inclination to wash their laundry on higher temperatures than individuals < 30 years. Yet, also in this case it cannot be assured.



Total N=9
Figure 2. Histogram of the activity "doing laundry – using washing machine", on the basis of participants age (error bars represent 95% confidence intervals).

Household energy conservation strategies (RQ 2)

The second aim of this research was to investigate which household behaviours people display that conserve energy. To answer this question data collected during the semi-structured interviews will be considered. With respect to the ways and means participants take to conserve energy at their homes, participants responses were analysed via inductive coding. The generated codes, example statements, and their frequencies, are illustrated in table 4. During the coding process, five main themes (codes) became apparent. These are the main strategies, performed by participants, to conserve energy. These were: using energy saving systems (1), turning off devices (2), reducing heating consumption (3), reducing water consumption (4), and predictive thinking (5).

Starting with the first main theme: using energy saving systems (1). This code consists of five sub-codes, namely: using energy saving light bulbs (1.1), using motion detector (1.2), using eco-function on dishwasher (1.3), using eco-function on washing machine (1.4), and using energy saving system on Computer/Phone (1.5). The most frequently represented code was: using energy saving light bulbs (1.1). In total, five out of nine participants indicated that they have installed energy saving light-bulbs in order to conserve energy at their homes. Moreover, one participant revealed that he/she has additionally installed a motion detector inside his room, to conserve even more energy (Participant 19) (1.2). However, the interviews showed that participants do not only use energy saving systems in terms of efficient lighting, but also have energy saving systems integrated inside their dishwashers and their washing machines. Overall, four participants stated to occasionally make use of a so-called eco-

function on their dish-washers and washing machines to save energy. These behavioural patterns are visualised by the codes 1.3 and 1.4. The last code respecting “using energy saving systems”, regards the usage of integrated energy saving systems on smartphones (1.5). Participant 13 stated to always turn on an eco-function on his/her phone, which aims at saving battery charging and hence thereby increases energy conservation. On the whole, using energy saving systems (1), was represented eleven times.

The second main code, namely turning off devices (2), consists of three sub-codes, which are: turning the lights off (2.1), turning off entertainment devices (2.2), and unplug devices when they are fully charged (2.3). Generally, this dimension refers to turning off devices, which are not used in a specific moment in order to prevent unnecessary energy consumption and thus increasing energy conservation. Three participants in total mentioned to turn off unnecessary lights to save energy (2.1). Additional three participants declared that they try to unplug devices if they are fully charged (2.3), and two participants stated that they try to turn off entertainment devices, such as TVs or music systems (2.2), if they do not need them anymore. In sum, turning off (non-used) devices was represented 8 times.

Concerning the third general code, reducing heating consumption (3), represented 15 times in total, it was observed that participants mostly try to reduce their heating consumption to increase energy conservation. As this was the most frequent represented code, it seems that reducing heating consumption is seen as the greatest potential energy saving source by the participants. Similarly, as the previous codes, this code is comprised of three sub-codes, namely: turning off the heating system (3.1), closing windows (3.2), and wearing sweaters indoors (3.3). To save energy, participants indicated that they partially turn off the heating system during the day and/or during the night (3.1). Besides this, all participants mentioned that they try to wear sweaters indoors before adjusting the heating system (3.3), and finally, two participants stated to pay especially attention to closing windows while the heating system is on to prevent energy waste (3.2).

The next general code:” Reducing water consumption” (4) was represented four times across all interviews. In this case, only one code was developed since participants statements were all considerably similar. As an example, participant 17 mentioned that he/she tried to reduce the time to shower in order to save energy. Whereas other participants simply declared that they try to limit their water usage to decrease their ecological footprints.

Lastly, the code predictive thinking (5), was observed by one participant (Participant 14). This strategy was noted by one participant only, yet it is not less worth to consider. The exact statement by participant 14 was: “[…] When I cook, I try to cook in advance so I can eat it in the next day, as well”. Interesting in this case is the fact that all other behavioural strategies participants perform to conserve energy rather happen “in the moment”. In other words, previous listed strategies concerning energy conservation rather focused on saving energy on “that specific day”, meaning that they can be

regarded as "short-term" strategies. Whereas the statement by participant 14 stands out since he/she thinks ahead by including "long-term" strategies into his/her way of thinking.

In conclusion, for increasing household energy conservation five main behavioural strategies were observed across nine participants. Mainly participants try to save energy by reducing their heating consumption, closely followed by using energy saving systems. Furthermore, by reminding themselves to turn off non-used devices, participants try to decrease unnecessary energy consumption and thereby increase conservation. Additionally, through consciously reducing water consumption participants try to save energy. Lastly, by thinking in the long-term, one participant demonstrated another important strategy for conserving energy at household.

Table 4.
Representation of participants energy conservation strategies.

Codes	Quote	N
1. Using energy saving systems		**11**
1.1 Using energy saving light bulbs	"We have energy saving light bulbs" (Participant 13)	5
1.2 Using motion detector	"[…] I have a motion detector with an included day light sensor to prevent unnecessary lighting" (Participant 19)	1
1.3 Using eco-function on dishwasher	"We have an eco-function on the dishwasher and washing machine […]" (Participant 15)	2
1.4 Using eco-function on washing machine	"[…] We have and use an eco-friendly option on dishwasher and washing machine" (Participant 13)	2
1.5 Using energy saving system on smartphone	"[…] I also have an energy saving system on the phone which I always have on." (Participant 13)	1
2. Turning off devices		**8**
2.1 Turning the lights off	"[…] turning off the lights if I do not need them" (Participant 21)	3
2.2 Turning off entertainment devices	"[…] Also turning off the TV and stuff [if not used] […]"	2
2.3 Unplug devices when they are fully charged	"[…] I charge everything just as long as it needs to be charged […]" (Participant 15)	3
3. Reducing heating consumption		**15**
3.1 Turning off heating system	"[…] I am turning off the heating system during the day […]" (Participant 21)	4
3.2 Closing windows [while heating system is on]	"[…] I close the windows [while I am heating], and I also close the windows while I am cooking so the heat of the stove stays in the room" (Participant 18)	2

3.3 Wearing sweater indoors	"[…] wearing a sweater [indoors] instead of raising the temperature" (Participant 21)	9
4. Reducing water consumption	"[…] When I am showering I try to shower not for too long." (Participant 17)	**4**
5. Predictive thinking	"[…] When I cook, I try to cook in advance so I can eat it in the next day, as well" (Participant 14)	**1**

Possible internal and external factors influencing energy conservation behaviour (RQ 3)

Interviews

The third aim of this research was to investigate which internal and external factors affect energy conservation behaviours. To answer this question data collected during the semi-structured interviews will be considered first.

Participants had to reflect on possible factors/reasons, influencing their energy conservation behaviour. During the analysis of the responses, it was especially interesting to see that many participants explained themselves using "external" factors/explanations for their behaviour. Individuals' social environment was often mentioned as a major contributing factor. For instance, participant 21 said:" My social environment definitely influences my energy conservation behaviour. If I am surrounded by people who pay more attention to it, it positively influences me. If not, then I am taking less care about it." Overall, three participants expressed that their personal social environment, particularly the people they are currently living with, strongly affect their energy conservation behaviour.

However, not only individuals' social environment was identified as external factor influencing individuals' energy conservation behaviour but also other external factors were identified across interviews. As an example, participant 16 stated that he/she is paying a monthly fixed fee for the electricity and water bills and that he/she therefore does not pay much attention towards his/her consumption. "[…] if I would pay it myself, I would probably pay more attention", he/she explained. Thus, under these circumstances the financing of one's consumption is identified as another external factor influencing energy conservation behaviour. A further external factor influencing energy conservation was specified by participant 17. As the entire world and its population is currently facing the corona virus pandemic, individuals are forced to spend their time at home. He/she declared that this has a great influence on his/her energy consumption and consequently also on his/her energy conservation behaviour. This is also in line with a statement of participant 20, since he/she mentioned that the more free time he/she has, the more he/she spends his/her time on entertainment devices. On the contrary, also internal factors were identified as influencing factors on participants energy conservation behaviour. The factor mood was mentioned by one participant (Participant 19). He/she

stated that if he/she is having for example a “bad day”, he she does not pay attention to energy conservation, despite the fact that he/she generally considers energy conservation as an important topic. Another interesting statement was given by participant 21, “[although] we have an eco-function on our washing machine, I am not using it because it takes too long.” Lack of time or rather even impatience might therefore be another internal factor, negatively impacting energy conservation at households.

Furthermore, during the interviews participants were asked whether they use/perform devices/activities which are part of their daily routine consciously or unconsciously. In other words, it was asked if participants reflect on their amount energy consumption or if they use/perform those devices/activities intuitively. Out of nine participants, only one stated to partly reflect on his/her energy consumption. Participant 13 stated that he/she is actually sometimes reflecting on it, for example, while using the toaster he/she pays attention to the heating stage in order to conserve more energy. On the contrary, all other participants stated that they do not consciously reflect on their amount of energy consumption while using those devices. As an example, participant 14 declared that using devices which are part of his/her daily routine is more like a habit and that he/she does not think about how much energy these devices consume. Statements concerning this question did not really differ across participants. Hence, participants using electrical devices, which are part of their daily routine, mostly use those devices intuitively without consciously thinking about it. Thus, the formation of habits might be another major possible internal factor/explanation for the failure of increasing energy conservation at participants households.

Focus Group

In a next step, results from the conducted focus groups were considered to identify potential internal and external factors that affect energy conservation behaviours.

Main ideas and findings are summarized in the following. The first factor, introduced by participant 1, was awareness. “Knowing how much energy a specific device consumes, would help me to conserve more energy” (Participant 22). He further explained that by having this kind of knowledge, it would make him more aware and thus result in him interacting more effectively with these devices. Moreover, by being more aware about effective usage of electrical devices, it would lead to a reduction of usage. Hence, this would conserve more energy. This statement received great consensus among participants. Having said this, participant 23 contributed another idea to the discussion. He explained:” also the price at the end of each month (so what I have to pay for my electricity bills), clearly influences my interaction with electrical devices. Thus, an internal reason for me to conserve more energy would be to know that if I reduce my consumption with a specific device, I would save more money.” This encouraged further discussion, as participant 24 reacted by saying that he regards this as difficult, since most households pay a fixed electricity bill each month and only

get a final invoice at the end of the year. To put things differently, he clarified that it might be difficult to detect behavioural flaws in an annual accounting. Furthermore, he added that for him, it would be easier to have a monthly accounting, hence he could better memorize what he had done differently in the previous month for example. As all participants agreed to that statement, it further stimulated the conversation. Participant 22 thereupon added:" having a list, which illustrates for example that leaving on the light for six hours costs approximately "3€", and has that specific effect on the environment would help me to assess as well as to adapt myself more effectively." Participant 26 agreed to that statement by saying that he believes that the costs involved probably is one of the main reasons for many households to conserve energy. Overall, all participants agreed to that, however, participant 23 argued a little differently by pointing out that although the costs involved might be a major contributing factor, he believes that the factor "time" is at least equally important to consider. "For example, if you have a relaxed day at home, one is probably more concerned to pay attention to one's energy consumption. However, if you are stressed and you have many things to do on that day, one does not pay attention towards energy conservation and stuff, because everything you are doing happens rather automatically (participant 23)." This statement was also approved by all participants. Participant 22 thereon got more into detail, by mentioning that the formation of habits is additionally a great factor to consider. "Things I am doing on a daily basis, by which I am simply not aware that I am doing them, because they happen automatically as for example every morning I am watching 15 minutes YouTube videos in order to get awake" (Participant 22). Furthermore, he clarified that he believes that the formation of habits promotes energy consumption and that tackling those by raising people's awareness would be very effective.

Increasing energy conservation in households (RQ 4)

Focus group

The final aim of this research was to investigate how energy conservation behaviours could be facilitated. To answer this question data collected during the focus groups will be considered first. In the following, main findings are outlined.

The first idea mentioned (participant 24) was that the government should implement punishments for inefficient energy use. He further explained that a government managed control system for household energy consumption would probably be effective. Moreover, he proposed that households, whose energy consumption is clearly higher than the averages amount of energy consumption should be punished by means of financial penalties. His proposed idea directly stimulated further discussion. Participant 22 and 23, claimed that this would probably rather be ineffective and simply not a fair solution. Participant 23 further clarified his opinion by pointing out the difficulty to implement such an idea. However, thereupon participant 25 proposed another idea. He suggested that inventing government-subsided rewards for especially energy conserving households

would be more effective. Rewards are not only more effective but also fairer, he explained. Overall, all participants agreed on the proposed idea and supported the idea that governmental rewards would be effective and consequently result in greater energy conservation at households. Furthermore, participant 23 brought another idea into context as he stated:" I believe it would be very effective if technical companies would start to integrate smart displays on their devices. So, that the user directly knows how much he/she consumes and directly receives information about the costs involved." Moreover, he also explained that a central display integrated in the house/flat, which gives you an indication on how much energy you consume per day would be very helpful as well. All participants agreed on the proposed idea to be effective. Additionally, participant 26 mentioned another idea. He stated that it would be beneficial if companies would provide more information concerning effective interaction with a specific device. Until today, he is still not sure whether he saves more energy by unplugging his coffee machine or if it actually costs more energy to always restart the device, he illustrated.

Governmental subsidies for increasing instalments of renewable energies at households was another interesting idea introduced by participant 26. All other participants approved this idea as worth considering it. Besides, participant 24 claimed that he actually believes that none of these ideas separately, would significantly decrease energy consumption. Further, in his opinion a multidimensional approach, combining multiple ideas, is necessary to achieve a desired change. This statement made by participant 24 received great encouragement by all participants. Taking the implementation of a multidimensional approach into account, participant 25 brought another interesting suggestion into context. From his perspective, the importance of this topic lacks education as he stated:" in school we never learned something about the individuals impact on energy consumption, sure we learned how energy is obtained in general, yet I still don't know the impact of a light-bulb for example […]". In other words, accurate information provision about effective interaction with recourses and electricity should be implemented in children's educational programmes.

Diaries

In a next step, data from the diary study were considered to identify further means of increasing conservation behaviour. At the end of each diary, participants were asked to briefly reflect on their amount of energy consumption. On the basis of this, participants were asked what they could have done in order to increase energy conservation within their households. The most important findings are presented in the following:

Table 5. illustrates the developed codes and its frequencies. In total, five codes were developed, representing the most frequent statements with respect to the question what participants could have done in order to increase energy conservation within their households.

The first code, namely:" Switching off lights", gathers all statements which were made concerning increasing energy conservation by switching off the lights. Statements such as:" I should pay more attention to my energy consumption in terms of electric lightening" (Participant 6); "Turn off the lights, when not being in the room" (Participant 1), were frequently made. The code "Switching off the lights" is represented 13 times and therefore the most frequent one.

"Turning off the heating", is the second most frequently represented code. This code, demonstrates all statements made with regard to reducing heating activities within households. "I could have turned off the heating in the living room and kitchen when it got warmer outside" (Participant 4), constitutes a good example statement. Overall, participants indicated 7 times, that turning off the heating system, would have been a good way to enhance energy conservation within their households. Additionally, participants partially stated that they even regulated the temperature whilst it was not necessary.

Next, the code" Entertainment reduction" was represented 7 times within all diaries. A good example statement of this code might be:" I could have spent less time on the internet and Netflix", (Participant 6). Participants often indicated that they were actually spending a great amount of time on their entertainment devices and that reducing this time would probably make a difference in terms of energy conservation.

The third most frequently represented code is: "Turning off devices if not used". Repeatedly, participants stated that they did not turn off devices such as radios, TV's or Computers etc. despite they were not using them anymore. Participant 3 declared:" I forgot to turn the radio off even though I left the room. I could have turned it off to increase energy conservation", which serves as a good example statement for this code. In total, participants indicated 4 times that they forgot to turn of electrical devices although they were not using them anymore.

Lastly, the least frequent represented code yet not less worth mentioning, is the code:" Reducing water consumption." This statement was given 2 times, only by Participant 11. "Taking a shorter shower", serves in this case an example statement. He explained that by reducing the time to shower, it would indeed result in energy conservation.

Table 5.

Codes for possible energy conservation strategies.

Codes	Quotes	N
Switching off lights.	"Turn off the lights, when not being in the room." (Participant 1) "I could have probably turned off the light in my room during the day while I was in it because it is actually quite bright without turning on the light." (Participant 4)	**13**
Turning off the heating	"I could have turned off the heating in the living room and kitchen when it got warmer outside." (Participant 4) "Turn heating off." (Participant 7)	**7**
Reducing water consumption.	"Taking a shorter shower." (Participant 11)	**2**
Entertainment reduction	"I constantly used my mobile phone, because of Spotify… and instead of watching community I could have read more" (Participant 6) "Maybe use my cell phone less." (Participant 11)	**7**
Turning off other devices if not used.	"Turning off the TV while sleeping." (Participant 9) "I forgot to turn the radio off even though I left the room. I could have turned it off to increase energy conservation." (Participant 3)	**4**

Discussion

The aim of the present study was to investigate household energy consumption as well as conservation behaviour among individuals/participants. Moreover, factors influencing participants' energy conversation behaviour and potential means/strategies for increasing household energy conservation were explored as well.

To begin with, the first research question, namely: "Which household behaviours do people display that consume energy?" To answer this research question, a qualitative diary method was used. Participants indicated both which activities they performed that consume energy as well as the duration of each activity. Before answering the research question, it is important to mention that it has been assumed that the higher the duration of each activity, the higher probably might be its level of

energy consumption. In other words, no results actually reflect the true amount of energy consumption but only illustrates participants' duration of usage.

Based on this, the results demonstrated that participants spent most time, consuming energy in their "personal/living- rooms." Especially time-consuming activities were participants' usage of their mobile phones and computers/laptops. This result seems reasonable as the inclusion of entertainment devices (laptops/computers, smartphones, TV's, etc.) in daily life, highly increased over the past years (Pothitou et al., 2017). Moreover, not only the possession and usage of entertainment devices increased but also that the growing demand for energy at households is, to a large extent, attributable to the possession of entertainment devices. Further, the authors explained this phenomenon by highlighting the raising accessibility of the Internet (Pothitou et al., 2017).

Alongside with participants usage of these devices (mobile phones and laptops), participants charging behaviour of those devices was measured as well. The results, however, were kind of contradictory. While participants on average used their laptops for a longer time period than their mobile phones, the duration of charging mobile phones was considerably higher than the duration of charging their laptops. While at first sight, this result seems counterintuitive, it might be explainable by so-called habitual charging behaviour (Wolbertus, Kroesen, van den Hoed, & Chorus, 2018). Within their literature review, the authors introduced the term "habitual charging behaviour." Although their research was centered around individuals charging behaviour of electric vehicles, this explanation could be attributable to individuals' mobile-phone charging behaviour as well. "Habitual charging behaviour" was described as being "opportunity-driven". In other words, it was observed that individuals have the inclination to re-charge their devices either in the morning and/or late in the evening. Since in the current study, participants often indicated to have charged their mobile-phones over-night, habitual charging behaviour might be an explanation for it (Wolbertus et al., 2018). Yet, further research would be necessary to verify this.

Moreover, concerning typical activities performed inside the kitchen, "washing dishes inside the dishwasher" and "cooking" were observed to be the most time-consuming ones. According to a study by Sukarno, Matsumoto and Susanti (2017), cooking devices were shown to have the longest duration of usage in relation to other electrical home devices. Additionally, they discovered that compared to other electrical household devices, cooking devices also consumed most energy in terms of kwh/year (Sukarno et al., 2017).

Furthermore, not only typical energy-consuming activities were explored, but also participants behaviour regarding the generation of illumination comfort was of interest. It was observed that participants mostly illuminated their personal/living-rooms. This is in line with previous results since participants spent most time inside these rooms according to their indications. On the one hand, results concerning illumination were partially in line with previous results. On the other hand, relatively high values were displayed by "lighting hall," presumed that participants probably did not spend that much time inside their halls. Nevertheless, this behavioural pattern could be explained by the formation of

habits. As reported by Robbins and Costa (2017), the term "habits" is defined as individuals' depictions of stimulus-response connections that are not directly based on any goals. Much more, they are evoked by contexts and/or environmental stimuli (Robbins & Costa, 2017; Marechal, 2010). In other words, they happen automatically. Considering participants lighting behaviour inside their halls, they may have done it automatically due to habit formation. Specifically, participants were probably used to switching on lights when entering a room, without consciously thinking about its necessity. Yet, other possible explanations should not be ruled out.

With respect to participants' cleaning and washing behaviour, the results illustrate that there might be energy consumption differences within the demographic variables age. Despite the fact that this cannot be stated with certainty as no significance level was included, the inclination that older individuals do their laundry not only more frequently but also on higher temperatures could be observed. Since researchers found that occupants between the age of 40 and 50 have the greatest comfort demand, compared to other age groups, the result seems reasonable (van den Brom, Meijer, & Visscher, 2018). In addition to that, a study by Belaid (2016), confirmed that the variable age indeed has a significant effect on energy consumption behaviour. The author revealed that with increasing age, an individual's energy consumption increases as well (Belaid, 2016). Nonetheless, it is still questionable if this can be attributed to participants' washing behaviour (doing laundry) Additionally, it is important to take into account that the number of people living in the household was not included in the analysis. Since the number of washings most likely increases with more people living in a household, the results have to be viewed with caution.

Furthermore, it was explored whether there might be correlations between variables. Due to the small sample size (N=12), the Spearman correlation was determined to be the most suitable measurement technique. The results demonstrated some significant correlations. Only stating the most interesting ones, it has been found that with increasing age, participants more frequently used their water-boilers. Furthermore, the older participants were, the more they used their hairstyling devices. When taking the study of Belaid (2016) into account, which states that "older" individuals tend to consume more energy, these findings can be supported.

With respect to the second research question, namely:" Which household behaviours do people display to conserve energy?", five main strategies for conserving energy within households were identified across interviews. In the first place, it has been found that in most cases, participants try to save energy through a reduction of their heating consumption. Secondly, it was discovered that to save energy, participants' installed energy-saving systems within their households as, for instance, energy-saving light-bulbs and motion detectors. Interestingly participants mainly installed energy-saving systems primarily for their lighting installations. Thirdly, it was detected that participants attempt to increase energy conservation by reminding themselves to turn off non-used devices. In the fourth place, the reduction of water-consumption was identified to be another strategy for conserving energy. Lastly, another strategy was discovered; however, only executed by one participant, namely

predictive thinking. Literature demonstrated that, reducing heating consumption, switching off lights, and switching off non-used devices are the most prevalently self-reported energy conservation strategies of individuals (Thondhlana & Kua, 2016). Overall, these strategies can be described as situational ones. According to Thondhlana and Kua (2016), situational factors can be described as personally experienced situations, which take the different contexts and the accompanying decisions into account. Certainly, there are multiple situational factors, and in order to determine their actual effectiveness, further research is necessary to elucidate their interplays (Thondhlana & Kua, 2016).

Research question three was:" What are possible factors influencing peoples' energy conservation behaviour?" For answering this research question, two data collection methods (interviews and a focus group) were used. Interestingly, both data collection methods revealed quite similar results. In total, six main factors influencing energy conservation behaviour were identified across interviews. "Social environment" (people one spends time with and/or even lives with) was determined as an influencing factor. Referring to the theoretical framework, studies illustrated that peoples' energy consumption and conservation behaviour is greatly influenced by their social environment (Bamberg & Mösner, 2007; Chen, Xu, & Day, 2017), supporting the identification of "social environment" as important influential factor.

Furthermore, the electricity bill and the factor "time" were identified as external factors influencing energy conservation behaviour. Moreover, as internal factors affecting energy conservation behaviour, "mood," "time – impatience," and "habits" were recognized. In light of literature, similar factors were identified. According to Zhou and Yang (2016), habits, social influence, and price level were shown to considerably affect an individual's energy conservation behaviour.

Consequently, the above-listed factors "social environment," "electricity bill," and "habits" are supported by literature.

Besides the interviews, the focus group revealed similar results, except for one factor. "Awareness" was additionally argued to have a major impact on energy conservation behaviour. On the one hand, literature demonstrated that individuals having greater levels of awareness do not necessarily display more efficient energy use (Pothitou, Hanna, & Chalvatzis, 2016). On the other hand, however, more recent findings suggest that knowledge and awareness indeed affect energy conservation among individuals (Niamir et al., 2020). Since studies partially contradict one another, further research is needed, testing the effect of awareness on energy consumption and conservation behaviour.

Lastly, research question four was:" What could be done in order to increase energy conservation at households?" In order to address this research question, responses from the diaries and focus group were used. After filling out the diaries, participants had to indicate what they could have done in order to increase energy conservation on that day. Based on this, "switching off lights", "turning off heating system", "reducing water consumption", "entertainment reduction", and "turning off devices if not used" were identified as situational energy conservation strategies. In order for these

situational strategies to be effective, additional factors are necessary to consider. Taking the Motivation-Opportunity-Ability model by Olander and Thogersen (1995) into account, behavioural change is most likely to be effective, if the factors motivation, ability, and opportunity are present as well (Thondhlana & Kua, 2016). Apart from that, the focus group revealed other promising energy conservation strategies, namely:" governmental subsided rewards" (for effective energy conservation), "smart displays" (with tailored feedback), and "raising education" (e.g., in school). Firstly, with "raising education" is meant that it would be beneficial to include the overall theme energy consumption and conservation into the educational context. Zhou and Yang (2016), state that knowledge is a crucial factor to consider when trying to increase energy conservation. Further, it was argued that knowledge affects an individual's awareness. This might strengthen an individual's feeling of responsibility, which, in turn, positively affects behavioural change (Zhou & Yang, 2016). Secondly, the strategy "governmental subsided rewards" is also supported by the article of Zhou and Yang (2016), as they stated that" incentive-based strategies" are indeed effective for achieving desired behavioural change. Moreover, "smart displays" (with tailored feedback), might also be a promising approach, as reviews have illustrated that tailored information and feedback are crucial points for effectively increasing energy conservation at households (Abrahamse, Steg, Vlek, & Rothengatter, 2007). Overall, since there is most likely no overarching approach due to the variety of factors that are necessary to consider, a multidimensional approach should be suggested.

Strengths and Limitations

Concerning the present study's limitations, social desirability can be noted as a first limitation, appearing as a confounding factor. According to Latkin, Edwards, Davey-Rothwell and Tobin (2017), social desirability bias refers to an individual's propensity to understate undesirable behaviours and to overstate desirable behaviours to generate a more likeable self. Since the collection of the data solely depended on participants' self-reported statements/indications, it might be the case that participants were prone to give social desirable responses. In this case, decreasing the duration of usage (eg. within the diary condition) in order to create a better or rather more likeable appearance might have influenced the results. Consequently, the validity of the present study might be threatened. Owing to the questionable validity, a naturalistic observation probably would have produced more valid results when measuring household energy consumption/conservation behaviour.

A second limitation which has to be addressed is the current situation. Since several months the world is facing one of the greatest pandemics in centuries, namely COVID-19. The (dutch/german) government obliged the population to stay inside their homes. Exceptions were only made for absolutely necessary reasons, as for example: buying food, visiting the doctor etc. For this reason, the representativeness of the study is very likely to be distorted due to the fact that individuals spent way more time inside their homes than under normal circumstances.

Thirdly, the set-up of the sample and the relatively small sample size ($N = 12$) in the diary condition can be considered as another limitation. Especially when reflecting on the results of the conducted correlations, it is important to examine those with caution. As the Pearson correlation sets primary conditions on the data, as for example normality etc. (Bakdash & Marusich, 2017), and none of these were met within the data, it was decided to use the spearman correlation. According to Astivia and Zumbo (2017), the spearman correlation is known to counterbalance these sample size effects. However, due to the number of tests, the probability of an increased type I error is not unlikely.

Lastly, the overall study's set up can be regarded as either a strength and/or limitation. On the one hand, since all data collection methods were self-developed and couldn't be validated in advance results cannot be stated with certainty. Simultaneously this might additionally affect the entire study's validity. On the other hand, due to the study's exploratory nature and its mixed method approach, much and diverse data could be gathered. In other words, the exploratory nature of this research enables to view this important topic from multiple perspectives.

Future research

Generally, there are many potential possibilities for conducting further research within this area. Future research could elucidate how to counterbalance the factors which negatively affect household energy conservation. This could be achieved by implementing a multi-dimensional approach. Alternatively stated, many small interventions addressing external and internal factors could be executed. As described in the theoretical framework, using social comparison, prompts, and increasing knowledge were shown to significantly reduce energy consumption. Thus, it would be interesting to observe whether applying all three strategies together, could further increase energy conservation in households. One primary goal behind that should be to investigate the factors interconnectivity.

Moreover, during the implementation of the diary study several participants indicated that due to keeping track of their energy consumption, their level of awareness was raised. Additionally, they reported that this positively influenced their energy consumption behaviour and simultaneously increased their willingness to conserve more energy. Consequently, including for instance an awareness based intervention beforehand may produce interesting results. To test whether there might be significant differences in energy consumption behaviour, an experimental design could be implemented. Thereby, one group could receive an awareness-based intervention before taking the diaries, which could be compared to a group receiving no prior instructions.

Conclusion

In conclusion, this research paper explored participants energy consumption and conservation behaviour. Interestingly, many results were in line with literature. A variety of variables were identified as playing a crucial role in predicting, analysing and influencing individual's energy

consumption/conservation behaviour. Research already elucidated multiple factors, affecting individual's behaviour in this field. Yet, there is still a great gap in research, since there is no fixed solution for addressing behavioural inefficiencies in household energy use. This further promotes the necessity of research in this field. As a final suggestion, a multidimensional approach, including all factors (external, internal, situational, intrapersonal etc.) would be necessary to achieve sustained behavioural change.

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Appendix

Appendix A

Appendix A1: Demographic data of participants in the diary condition

Table 1.
Demographic data participants diary study.

Participant	**Gender**	**Age**
Participant 1	Male	28
Participant 2	Female	24
Participant 3	Female	36
Participant 4	Female	23
Participant 5	Female	53
Participant 6	Female	21
Participant 7	Male	21
Participant 8	Female	50
Participant 9	Female	30
Participant 10	Female	42
Participant 11	Male	25
Participant 12	Male	23

Table 2.
Characteristics of the sample.

Demographic variables	**N**
Mean age in years (SD)	31.3 (10.85)
Gender	
Female	N = 8
Male	N = 4

Appendix A2: Demographic data of participants in the interview condition

Table 3.
Demographic data participants interview study.

Participant	**Gender**	**Age**
Participant 13	Female	20
Participant 14	Male	21
Participant 15	Female	20
Participant 16	Male	23
Participant 17	Female	21
Participant 18	Male	24
Participant 19	Male	22
Participant 20	Female	21
Participant 21	Female	24

Table 4.
Characteristics of the sample.

Demographic variables	**N**
Mean age in years (SD)	21.77 (1.56)
Gender	
Female	N = 5
Male	N = 4

Appendix A3: Demographic data of participants in the focus group condition

Table 5.

Participant	**Gender**	**Age**
Participant 22	Male	24
Participant 23	Male	23
Participant 24	Male	26
Participant 25	Male	22
Participant 26	Male	24

Appendix A4: Informed consent

Informed Consent

'I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research as mentioned before. My questions have been answered to my satisfaction. I agree of my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time.
If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely anonymous. My personal data will not be disclosed to third parties without my express permission. If I request further information about the research, now or in the future, I may contact Kira Bibic k.bibic@student.utwente.nl) or Dilan Ince (a.d.ince@student.utwente.nl)
If you have any complaints about this research, please direct them to the secretary of the Ethics Committee of the Faculty of Behavioural Sciences at the University of Twente, Drs. L. Kamphuis-Blikman P.O. Box 217, 7500 AE Enschede (NL), telephone: +31 (0)53 489 3399; email: l.j.m.blikman@utwente.nl).
Signed in duplicate:

....
Name Participant Signature

I have provided explanatory notes about the research. I declare myself willing to answer to the best of my ability any questions which may still arise about the research.'

....
Name researcher Signature
Please indicate your gender and age here:
O Male O Female Age: ___

Appendix B

Appendix B1:

Start your Diary:

Dear Participant,

fill out the following tables.

Please indicate your **participant number** here: _____

Please indicate the **date** here: _____

Kitchen

Explanatory information:
While filling out the tables, please note that if you did not complete one of the following activities or you simply do not have one of the following listed devices, you can leave it free.

- **Energy saving option**: nowadays many dishwashers include for example an "eco-function", which is aimed at conserving more energy. If any of your devices include such an option, please indicate it in the last column.
- Please remember: the last row is left free so that you have the possibility to add a device you used, which is not included in the given table.

Activities	**How often did you use it/ do it?** (please give your answer by using simple strokes)	**For how long did you approximately use it/ do it?** (please give your answer in minutes and/or hours)	**Does your device have an energy saving option? (**If yes indicate what and if you used it?)
Using the dishwasher			
Washing the dishes by hand			
Cooking (using the stove)			
Cooking (using the oven)			
Water Boiler			

Toaster			

Bathroom

Activities	**How often did you use it/ do it?** (please give your answer by using simple strokes)	**For how long did you approximately use it/ do it?** (please give your answer in minutes and/or hours)
Taking a shower		
Taking a bath		
Using the toilet		
Washing hands		
Hair dryer		
Other hair styling devices (such as: hair straightener, curling iron)		

Living room/personal room (free time and work)

Activities	**How often did you use it/do it?** (please give your answer by using simple strokes)	**For how long did you approximately use it/ do it?** (please give your answer in minutes and/or hours)
Watching television		
Using Laptop or Computer		
Using the printer		
Using mobile phone		
Using Tablet		
Using Game consoles		
Using music system		

Explanatory information:

- Technological devices such as laptops, mobile phones or tablets etc. are working with a rechargeable battery. Please indicate whether you have charged your device and if yes for how long.
- Please remember: Extra lines were added, in case there are other devices which you might have charged today. Additionally, if you charged your device overnight, please indicate it in the last column by writing ("overnight").

Device	**Did you recharge your device?** (yes/no)	**For how long did you approximately recharge your device?** (answer in minutes/hours)
Mobile Phone		

Laptop		
Tablet		

Entire House/Flat

Light

Light per Room	**How long did you approximately leave the lights on? (**answer in minutes and/or hours possible)	**Did you leave on the lights in any of these rooms even when you were not in it? (**If yes, please indicate for approximately how long this was the case per room. If not, just leave it free).	**Are you using any energy saving systems?** (in this case for example: energy saving light bulbs, motion detector etc.; If yes please indicate what for the belonging room).
Bathroom			
Kitchen			
Living Room			
Bedroom			
Hall			

Heating regulation (Generating thermal comfort)

Heating per Room	**How long did you approximately regulate the temperature in the room? (**answer in minutes and/or hours possible)	**Did you regulate the temperature at night?** (answer: Yes/No)	**On a scale from 1 (low) to 5 (high), How low/high did you regulate your heating system?**	**Are you using any energy saving systems?** (such as: automated thermostats etc.)
Bathroom				
Kitchen				
Living Room				
Bedroom				
Hall				

Cleaning/washing

Did you do your laundry today? (yes/no)	**If yes, how often? (once, twice…)**	**What temperature did you set for the laundry?**

Did you use your Vacuum cleaner today?	**If yes, for how long?** (answer in minutes)	**On which load did you set your vacuum cleaner?** scale 1(low)-5(high).

Did you use your dryer today? (yes/no)	**If yes, how often? (once, twice…)**	**What temperature did you set?**

Did you hang up your laundry today? (yes/no)

Follow up questions

You arrived at the last step of today's diary. Now please answer shortly the following questions.

Question 1: In your opinion, do you think your amount of energy consumption was high/normal/low today, compared to the general population? (Please explain why in 1-2 sentences)

Answer:

Question 2: Do you think you could have conserved more energy today? (yes/no)

Answer:

Question 3: If yes, what could you have done in order to increase energy conservation at your home?

Answer:

You finished today's diary. Thank you very much for your participation!

Appendix B2:

General questions (Overview questions)

1. Do you live in a shared flat/house and if yes how many people live in your home? / Do you live alone?

2. For you personally, which electrical devices are the most important?
3. Which electrical devices are part of your daily routine?
4. While using those devices, do you reflect on its energy consumption or do you use them intuitively? (Rephrased: Do you actually think about the device's energy consumption or would you describe the usage rather as a habit?)
5. How many electrical devices for entertainment (non-essential) do you own? (such as game consoles, sewing machines,tv etc.)?(please give some examples)
6. Which of these do you use most frequently?
7. While using those devices, do you reflect on its energy consumption or do you use them intuitively? (Rephrased: Do you actually think about the device's energy consumption or would you describe the usage rather as a habit?)

More specific questions with regard to energy consumption behavior

1. How often do you do your laundry (within one week)?
2. At what temperature do you usually wash your laundry? Why?
3. How often do you take a shower (within one week)?
4. How long do you approximately shower? Why?
5. Do you use tools to help clean your household, e.g vacuum cleaners, vacuum robots, etc.?
6. How often do you use these?
7. If you have a cell phone or a laptop-computer, how often do you charge it (within one week)?
8. Do you charge overnight?
9. Which activities do you perform that entail water heating (e.g. boiling tea, washing your laundry, doing the dishes)?
10. How often do you perform these activities (within one day)?
11. During the heating period, how many rooms are you keeping warm using your heating system?
12. Do you have a “Smart thermostat”?
    1. If yes, at which daily setting?
    2. If no, when do you heat and when not?
    3. At what temperature do you usually set your heater?
13. Do you normally wear sweaters indoors?

14. At what stage do you usually adjust your heating system during the heating period? (stage 1-5)
15. Do you also use your heating system at night?

Interview questions with regard to energy conservation behaviour

1. For you personally, how important is it to conserve energy at your home? *(from a scale from 1 (low) to 10 (high)*
2. What do you do in order to conserve energy?

3. **By which devices/activities do you mostly pay attention to energy conservation? In other words, with which activities/devices are you most conscious about your energy consumption?**
    a. **By which activities/devices do you have the highest willingness to conserve energy?**
4. Do you have energy saving systems in your home (explanation: such as an eco-function on your dishwasher/ energy saving light bulbs)?
    a. If yes, what kind of energy saving systems do you have?
    b. If yes, how many?
5. **By which devices/activities do you not pay attention to its energy conservation? In other words, with which activities/devices are you least conscious about your energy consumption?**
    a. **By which activities devices do you have the lowest or least willingness to conserve energy?**

6. By which activities do you find it most difficult to conserve energy?
    a. If yes, please explain why?

7. Can you think of anything else that influences your energy conservation behaviour?

Appendix C

Appendix C1

Table C1:
Spearman correlation of participants gender, age, and energy consumption total.

		Gender	Age	Kitchen Total	Bathroom Total	Living/-Personal room Total
Gender	Correlation Coefficient	-				
	Sig. (2-tailed)					
Age	Correlation Coefficient	-.411	-			
	Sig. (2-tailed)	.184				
Kitchen Total	Correlation Coefficient	-.359	.183	-		
	Sig. (2-tailed)	.252	.570			
Bathroom Total	Correlation Coefficient	-.103	.239	.608*	-	
	Sig. (2-tailed)	.751	.454	.036		
Living/-Personal room Total	Correlation Coefficient	.102	-.277	-.021	.281	-
	Sig. (2-tailed)	.751	.383	.948	.377	

Table C2.
Spearman correlation of participants age, gender and charging activities.

		Age	Sex	Charging Total	Charging mobile-phone	Charging Laptop	Charging other devices
Age	Correlation Coefficient						

	Sig. (2-tailed)	-					
Sex	Correlation Coefficient	-.411					
	Sig. (2-tailed)	.184	-				
Charging Total	Correlation Coefficient	.218	-.205				
	Sig. (2-tailed)	.497	.523	-			
Charging mobile-phone	Correlation Coefficient	.065	.103	.739**			
	Sig. (2-tailed)	.841	.751	.006	-		
Charging laptop	Correlation Coefficient	.007	.026	.206	-.358		
	Sig. (2-tailed)	.982	.936	.520	.253	-	
Charging other devices	Correlation Coefficient	.106	-.487	-.029	-.238	-.123	
	Sig. (2-tailed)	.742	.108	.928	.372	.704	-

**Correlation is significant at the 0.01 level (2-tailed)
Total N=12

Table C3.
Spearman correlation of participants gender, age and lighting activities.

	Age	Sex	Light Total

Age	Correlation Coefficient			
	Sig. (2-tailed)			-
Sex	Correlation Coefficient	-.411		
	Sig. (2-tailed)	.184		-
Light Total	Correlation Coefficient	-.174	-.180	
	Sig. (2-tailed)	.589	.577	-

**Correlation is significant at the 0.01 level (2-tailed)
Total N=12

Table C4.
Spearman correlation of participants age gender and kitchen activities.

		1.	2.	3.	4.	5.	6.	7.	8.
1.Age	Correlation Coefficient	-							
	Sig. (2-tailed)								
2.Gender	Correlation Coefficient	-.411	-						
	Sig. (2-tailed)	.184							
3.Using dishwasher	Correlation Coefficient	-.092	-.413	-					
	Sig. (2-tailed)	.776	.182						
4.Washing dishes by hand	Correlation Coefficient	.253	.129	-.687*	-				
	Sig. (2-tailed)	.472	.689	.014					
5.Cooking	Correlation Coefficient	.290	-.154	.097	.232	-			
	Sig. (2-tailed)	.360	.632	.763	.468				
6.Water-boiling	Correlation Coefficient	.583*	-.518	-.079	.127	.073	-		
	Sig. (2-tailed)	.047	.084	.808	.695	.822			
7.Using toaster	Correlation Coefficient	.002	.110	-.004	.243	-.133	.097		
	Sig. (2-tailed)	.995	.735	.991	.446	.680	.765		
8.Using other devices	Correlation Coefficient	.176	.114	.335	.193	.092	-.210	.543	
	Sig. (2-tailed)	.583	.723	.287	.548	.776	.513	.068	

Table C5.
Spearman correlation of participants age, gender and activties performed inside the LV.

		1.	2.	3.	4.	5.	6.	7.	8.
1.Age	Correlation Coefficient	-							
	Sig. (2-tailed)								
2.Gender	Correlation Coefficient	-.411	-						
	Sig. (2-tailed)	.184							
3.Watching television	Correlation Coefficient	.271	-.411	-					
	Sig. (2-tailed)	.394	.184						
4.Using Laptop/ Computer	Correlation Coefficient	-.133	.410	-.744**	-				
	Sig. (2-tailed)	.680	.186	.006					
5.Using mobile-phone	Correlation Coefficient	-.179	-.154	.333	-.343	-			
	Sig. (2-tailed)	.578	.634	.290	.276				
6.Using game consoles	Correlation Coefficient	-.493	.807**	-.401	.239	-.046	-		
	Sig. (2-tailed)	.104	.002	.197	.455	.887			
7.Using music system	Correlation Coefficient	.202	-.355	-.101	.187	-.541	-.152	-	
	Sig. (2-tailed)	.528	.257	.754	.561	.069	.638		
8.Using printer	Correlation Coefficient	.556	-.571	.247	-.429	-.140	-.461	.129	-
	Sig. (2-tailed)	.061	.052	.440	.164	.663	.132	.689	

Table C6.
Spearman correlation of participants age, gender and bathroom activities.

		1.	2.	3.	4.	5.
1.Age	Correlation Coefficient	-				
	Sig. (2-tailed)					
2.Gender	Correlation Coefficient	-.411	-			
	Sig. (2-tailed)	.184				
3.Taking a shower	Correlation Coefficient	-.103	.077	-		
	Sig. (2-tailed)	.751	.811			
4.Washing the hands	Correlation Coefficient	.169	-.104	.070	-	
	Sig. (2-tailed)	.600	.748	.830		
5.Using hair style devices	Correlation Coefficient	.630*	-.466	.291	.305	-
	Sig. (2-tailed)	.028	.127	.360	.335	