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Residential electricity- and water consumption:

A study on actor commitment in consumption reduction

Master's thesis in Management and Economics and Innovation

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Abstract

Residential housing consumes more than one third of Sweden's electricity and in order to minimise the reliance on fossil fuels, the real estate industry needs to decrease its consumption. Therefore, the aim of this report is to investigate how residential electricity- and water consumption can be reduced. The report analyses products' and services' potential in reducing residential electricity- and water consumption as well as Gothenburg residents' and housing companies' commitment in consumption reduction. A regression analysis was performed to identify predicting variables and found that resident surface area, number of occupants and heating type are significant predicting factors for electricity consumption. The effects of individual metering and billing on water consumption was analysed and it was found to be a viable initiative for one of the examined areas but for the other area it was only a solution in the short term. It was also found that housing companies reduce consumption by performing renovations and continuous maintenance on their properties and does not interfere with their residents' consumption behaviour. Residents do not know how much they consume, and housing companies do generally not provide this information if electricity and water is included in the rent. Residents' initiatives to lower consumption are consequential but not intended and their aspirations are not realised because of inconvenience. Previous research has highlighted the role of price and income in consumption behaviour. These results show that consumption behaviour is to a greater extent affected by information and feedback systems of consumption data. Furthermore, gamified systems have the opportunity of providing real time data and engaging users in consumption reduction with game mechanics.

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1. Introduction

The urban population in the world is growing, which has led to a growing pressure on the access to clean energy and water resources (Mcgranahan & Satterthwaite, 2014). The changes in household consumption have contributed to economic and environmental problems such as climate change, peak electricity demand and water shortages. In year 2016, residential housing consumed 29 percent of Europe's electricity. 43 percent of this electricity was generated with fossil fuels and only 29 percent generated with renewable sources (European Environment Agency [EEA], 2018). The electricity production in Sweden is 41 percent hydropower, 40 percent nuclear, ten percent wind power and nine percent mainly from combustion-based generation. The housing and service sector consumed 146 TWh which stands for 39 percent of the total energy consumed in Sweden. Of the total energy consumed by the housing and service sector, 73 TWh is electricity. The energy required for housing and service is met by mostly renewable sources, but fossil fuels are still needed to meet the demand (Swedish Energy Agency, 2018). The emergence of solar photovoltaics helps meet the demand of electricity but produces another problem, a duck-shaped net load curve, since demand during midday hours is low when generation potential of solar photovoltaics is high (Lew & Miller, 2016). To avoid a potential reliance on fossil fuels to meet the peak demand of the net load curve, and in general, electricity consumption must decrease.

In agriculturally dependent regions in China, India and the US etc., groundwater is currently being depleted. This causes more noticeable damage on a local scale but also causes global problems, such as increasing sea levels (Aeschbach-Hertig & Gleeson, 2012). Of the total residential water consumption, it is common to calculate that 35 percent is hot water which, in turn, corresponds to 15 percent of the total residential electricity consumption (Swedish Energy Agency, 2012). Even if only 22 percent of consumed water in Europe is on the account of municipal withdrawals (FAO, 2016), the connection between consumption of hot water and energy motivates a dissuasion on water consumption. Any behavioural changes in consumption are likely transferred to other aspects of consumption.

Energy- and water consumption is a fairly well researched area in what methods can be used to lower the consumption (Coelho & Andrade-Campos, 2014; EEA, 2012; EEA, 2017; Enshassi et.al. 2017; Vilanova & Balestieri, 2014; Leiby & Burke, 2011; Weissman and Miller, 2009). Despite the attention, there seems to be a gap in the research in how to create long-lasting commitment in changing behaviour for reducing electricity- and water consumption. This commitment is favourably made by all participants of society, leading into the subject of this thesis, residential consumption.

1.1 Background

This thesis is written in collaboration with the companies operating through Coboom - Volvo, Stena and CGI. Coboom exists to, in collaboration with students, find new perspectives from the companies' existing industries, as well as emerging industries, in order to reach a more sustainable society. These perspectives and insights can be used in the development of their companies and in the development of new solutions. Because of the fact that the housing industry stands for 29 percent of the total energy consumed in Europe, where 43 percent is produced by fossil fuels, Coboom wants to find solutions for this problem. One way to decrease the total energy consumption and reach a more sustainable society is to reduce electricity- and water consumption, both at an industrial and individual level. Though, Coboom are specifically interested in understanding how to engage residents in reducing their electricity- and water consumption.

1.2 Aim

This report aims to investigate how residential electricity- and water consumption can be reduced for a more sustainable society. In order to reach the purpose, emphasis is placed on resident behaviour and knowledge regarding their consumption, as well as the effects of different methods in lowering electricity- and water consumption, implemented by private and public actors. Together with a market analysis of electricity- and water saving devices, the report intends to give recommendations on how residential electricity- and water consumption can be reduced and how commitment in consumption reduction can be sustained in the long term.

1.3 Delimitations

The scope of the study is limited to Sweden, Gothenburg in particular. Therefore, the results and methods might not be applicable for other countries as culture, norms, habits etc. differ. A long-term solution is desirable but hard to measure due of the time constraints of writing this report. Because of this, the given recommendations will not be tested to measure the actual effectiveness. Further, we have not been able to try the feasibility of the recommended methods to see how the residents' behaviour change when using the proposed gamified system. Due to not being able to access real time consumption data to communicate to the users, the recommendations are theoretical and needs further testing of validity. Moreover, the residential electricity- and water consumption reduction is assumed to be environmentally good due to the uniform usage reduction of the electricity generation sources. Any total consumption decrease will also decrease the use of fossil fuels.

1.4 Research Questions

The argued importance of decreasing the total energy consumption and reliance on fossil fuels, together with the lack of research on how to keep residents long-term engaged in their electricity- and water consumption has led to the following research question, with accompanying sub-questions:

> RQ: How can consumer commitment in reduction of residential electricity- and water consumption be sustained?
>
> > *Q1: What effect do price models have on electricity- and water consumption?*
> > *Q2: What products or services can lower electricity- and water consumption?*
> > *Q3: What role do housing companies play in facilitating the reduction of electricity- and water consumption?*
> > *Q4: How involved are residents in their electricity- and water consumption?*

1.5 Outline

The remainder of the report is structured as follows. Chapter 2 describes the methods used to reach the study's aims. Chapter 3 provides the literature review forming the basis of the analysis of the paper. The literature review describes approaches for understanding consumer behaviour and consumption, residential electricity- and water consumption and how gamification can be used to change behaviour. Chapter 4 presents the results and analysis of the gathered data. Finally, the conclusions of the research are presented in chapter 5.

2. Methodology

This chapter aims to describe the methods used to reach the goals of this study i.e. to investigate people's knowledge about their energy- and water consumption and how one can decrease the consumption through various methods. The following subchapters describes the literature review, data collection and data analysis.

2.1 Literature Review

The literature review has been an ongoing process during the writing of this thesis as new information has led to the needs of investigating some literature further, discarding some literature and finding new literature. The literature reviewed was used as a basis for the formation of interview questions, as well as for the analysis of the collected data. The used literature was mainly searched for on the web-platforms Google Scholar and Chalmers Library using the keywords: water consumption, energy consumption, electricity consumption, consumer behaviour, consumption behaviour, sustainable consumption, habits and gamification.

2.2 Data Collection

The qualitative data regarding residents' behaviour and knowledge was collected by interviewing seven people living in apartments, in the municipality of Gothenburg. The interviews were of a semi-structured character allowing for follow-up questions and clarifications to get a higher degree of understanding of the residents' behaviours, aspirations and knowledge. The interview objects were chosen from an aspect of convenience and availability, where we actively searched for different demographics of the residents. One of the sub-questions of this study is to investigate residents' knowledge of electricity- and water consumption. Because of this, the first questions asked to the residents was open questions about the residents' sustainability actions and behaviour in their home. This was to understand their level of knowledge regarding the effects of electricity- and water consumption. Later on, the questions were more specified for electricity- and water consumption.

Three expert interviews were conducted, one with an innovation manager who has worked with lowering energy consumption through gamification, one with a head of housing management at Chalmers Studentbostäder (CSB), and one with an energy manager within housing development working at a big housing company in Gothenburg, hereafter referred to as

Company X[1]. The expert interviews were of a semi-structured character and provided insights about the market, as well as provided us with historical data on energy- and water consumption before and after the use of individual metering and billing. Moreover, an interview with the vice president of Greenely, an application that visualise users' electricity consumption, was conducted to better understand the service they provide and what electricity reduction users have achieved after signing up to the service.

Quantitative data regarding energy consumption was collected from historical data by the company Greenely which, in turn, collects the data from the Swedish power grid after the user of the service has signed a power of attorney to retrieve the electricity consumption data. Historical data about water consumption and the effects of individual metering and billing was collected from Company X.

2.3 Data Analysis

Depending on the type of the gathered data, it was analysed in a qualitative or quantitative manner. The qualitative analysis was based on the interviews while the quantitative analysis was based on electricity- and water consumption data.

2.3.1 Qualitative Analysis

The interviews with residents were first processed at a resident level in which interesting themes and answers were found. From the seven interviews, analytical themes were established which were based on the aggregation of the residents' answers. These themes formed the basis for the second analysis of the answers. During this analysis, specific emphasis was placed on the themes that concerned the residents' current behaviour in the home, aspirations and knowledge regarding their electricity- water consumption. The interview material was anonymised, and the interviews are referred after their number. See Appendix II for an interview overview and quotes.

The analysis of expert interviews followed a similar pattern as with the residents. The first expert interview was analysed with regards to the literature review of electricity consumption and gamification, it also worked as a basis for how the service Greenely can be further gamified. The following two interviews of housing company experts were analysed, first separately to

[1] Company X kindly agree to take part of this analysis, but wish to remain anonymous

find interesting themes and then analysed in conjunction with the literature. The emphasis was placed on individual metering and billing, initiatives to lower residential consumption and their overall sustainability work.

2.3.2 Regression Analysis

A regression analysis was performed in the program R, using the data provided by Greenely. The Excel sheet with the data for each user of the application contained, among others, the following data points:

- Municipality
- Facility surface area in square meters intervals
- Heating types
- Facility type
- Construction year intervals
- Number of occupants
- Electricity consumption in kWh/year

The occupants were given in exact numbers while the categorical variables facility surface area in square meters and construction year of the residence was given in an interval. Used heating technology, facility type and municipality were also transformed into categorical variables. The electricity consumption data had been collected at least one year before, and at least one year after signing up to the application, only data before signing up to the application was used. The main variable of analysis, y, was the energy consumption and how it varied depending on the multiple variables.

The initial sample size of Greenely's data were 757 observations. However, the sample size was reduced for the regression analysis. Greenely recommended separating the samples denoted 'intercept' and 'HDD', in their data. The calculations derived from the 'HDD' model was to be considered higher quality as the intercept model data indicated a "poor fit", derived from "problematic behaviour" or missing data points. The 'intercept' sample was subjectively selected by Greenly and why it was recommended to not use the sample was not further motivated. The sample size, removing one extreme value and only using the HDD denoted data sample resulted in 522 observations. The provided Excel sheet also included several other data points, including both aggregated consumption difference and percentage consumption difference, date of signing up to the service, predicted usage, etc. These data points were not considered to be able to predict energy consumption and was, therefore, left out of the analysis.

The multiple regression analysis assumes a linear relationship between the predictor variables and the outcome variable; multivariate normality: the residuals are normally distributed; no multicollinearity: no high correlation between the independent variables; and homoscedasticity: the variance of the error term, ε, is evenly distributed over the values of the independent variables. Multicollinearity can be tested using variance inflation factor values. However, since the used model includes categorical variables, the test is significantly harder to conduct and interpret and was, therefore, not performed. This limits the validity of the regression model but can still give an indication on predicting variables.

3. Literature Review

The literature review provides an empirical and theoretical context which the analysis is built upon. Further, it has worked as the basis for the empirical research and the formation of interview questions to residents and experts. The chapter starts with explaining consumer behaviour and consumption. Building into literature on electricity- and water consumption in particular. Lastly a description of gamification as ways to engage users are presented.

3.1 Consumer Behaviour and Consumption

Consumption among individuals is shaped by complex and interrelated forces which affect peoples' perceptions about themselves, their desires, and how they behave in changing situations. These forces include demographics, economic factors, personal factors, societal and technological factors, and marketing. Including, among others: habits, taste, culture, prices, income, trade, supply of goods and services globalisation and technological innovations (Mont & Power, 2010; Power & Mont 2010). Understanding all forces and their impact on consumption behaviour is almost impossible. The intricacy of consumption behaviour and the failure to address it will culminate in failure to find the necessary changes in consumer behaviour and consumption patterns. Among these forces, policy makers understand well how income and price affect consumption, while habits and culture are usually less understood (Mont & Power, 2010).

Tukker, Charter, Vezzoli, Stø & Andersen (2017) explain that changing consumer behaviour is only likely if the three components: motivation/intent; ability; and opportunity are confronted at the same time. The substitute opportunities should be as attractive or considered better than the current way of doing things. Not only in functionality but also in terms of intangible attributes like identity creation, symbolic meaning, and manifestation of dreams, hopes and expectations. Only providing informative instruments is inadequate for sustaining behavioural changes (Tukker et al., 2017).

Consumer behaviour and their role to mitigate climate change, is to a high degree shaped by the society through social norms, habits and available infrastructure. Together, these form a 'lock-in' which restricts the consumers' ability to independently act on their free choices, resulting in a lack of control over their actions. As long as existing systems and institutions remain the same consumers are not likely to change either (Tukker et al., 2008). Therefore, a change in behaviour depends on structural changes and collective efforts from all involved parts of the society including consumers, producers and government (Tukker, Sto & Vezzoli, 2008).

3.2 Electricity consumption

It seems electricity is a particularly complicated area for the promotion of sustainable consumption, and the household sector appears to be an inconsistent target group (Fischer, 2008). Instead of considering the household sector as a commercial group, Kavousian, Rajapogal and Fischer (2013) propose a policy for disaggregating energy consumption into determinants. These determinants were produced by reviewing residential electricity consumption models and building science literature, and include the following: weather and location; physical characteristics of the building; appliance and electronic stock; and occupancy and occupants' behaviour towards energy consumption (Kavousian et al., 2013)

Feedback on household electricity consumption has been shown to reduce consumption and the savings depend on type and quality of the feedback. It is important that the information presented to the consumer is relevant and facilitate sustainable decision making (Petersen, Shuntorov, Janda, Platt & Weinberger, 2007). Little research has been done to analyse the most efficient feedback regarding consumption for consumption reduction. Though, Karjalainen (2011) found that the most valued feedback on electricity consumption are presentations of aggregated costs, appliance-specific breakdown and historic comparison.

Darby (2001) breaks down electricity-consumption feedback into three different categories: direct feedback, e.g. self-meter readings; indirect feedback, e.g. more frequent billing and in-depth bills; and inadvertent feedback, e.g. learning by association when acquiring new electrical equipment. It was found that direct feedback by itself, or in combination with other feedback types, was most efficient in reducing electricity consumption (Darby, 2001). This is consistent with the findings of Petersen et al., (2007) who found that feedback, in conjunction with education and incentives significantly reduced electricity consumption in college dormitories. It was also found that the quality of the feedback mattered, with high quality feedback, defined as visual graphs and comparisons, compared to low quality feedback, defined as simple number data and no visualisation or graphs, reduced electricity consumption by 55 percent versus 31 percent (Petersen et al., 2007).

3.3 Water Consumption

For a sustainable water management, it is essential to use market-based instruments. Meaning that the water prices and tariffs arrangements must reflect the true costs of water. Economic instruments are such that can be used to encourage the development of efficient measures, technological innovation and changing behaviour (EEA, 2012). Economic instruments, also called economic policy instruments (EPIs), consists of various policy tools such as pollution taxes, deposit-refund systems and performance bonds. They are designed and implemented with the intentions of adapting individual decisions to collectively agreed goals. The general characteristics of economic instruments is that they culminate in change or influence behaviour through their effect on the market. They are used as methods to contemplate external costs, i.e costs forced upon the public during production and consumption of goods and services. Some of the benefits of EPIs can be to establish long-term incentives for technological innovation, encouraging efficient allocation of water resources or promoting efficient water usage (Lago, Mysiak, Gómez, Delacámara & Maziotis, 2015).

Two common approaches for conserving water are raising awareness and metering. Campaigns to raise awareness about water consumption can include advertising through the common media types by the government, local authority, education programmes in school, water companies, etc. Metering is a tool that provides accurate feedback and information of water consumption, which is important to realise how much water is actually used. Metering is also a necessity for the water tariff structure and for setting volumetric pricing (EEA, 2012).

Several studies of the EEA show that increasing water prices is a useful instrument to manage the water demand of households. Though, a frequent obstacle to the implementation of cost recovery is the insufficient metering infrastructure in the household sector, which results in a short of incentives to use water wisely (EEA, 2012; EEA, 2013; EEA, 2017). While increased water prices generally reduce the water consumption, the most effective way to reduce household water consumption is when water pricing policies are implemented together with other non-pricing policies. Non-pricing policies include maintenance such as finding and repairing leakages in water supply networks, improved technology for more efficient household apparatuses and water saving devices (EEA, 2017). Water saving devices can lower the water consumption with approximately 20 percent, this also relates to an electricity saving of 1500-2200 kWh/apartment and year (Swedish Energy Agency, 2012). Such devices can be low flow shower heads or dual flush toilets etc. The aggregated non-pricing policies alone have the possibility to save up to 50 percent of the water consumption (EEA, 2017). Other factors affecting the water demand are income and household size, where the water consumption increases proportionately more than the increase in income and household size (EEA, 2013). Tiefenbeck, Wörner, Schöb, Fleisch and Staake (2019), proved that real-time consumption feedback substantially reduces consumption, even when participants did not voluntary opt in, or had any incentives for saving energy costs. A smart shower meter visualised the participants' energy efficiency on a monitor with a polar bear on melting ice. The polar bear animation was tied to energy efficiency classes and changed when a transition from one class to another occurred, this resulted in a 11,4 percent reduction in energy consumption. Although, the cause of the behavioural change was not the polar bear itself, but rather the feedback on consumption (Tiefenbeck, 2019).

The effectiveness of different solutions in reducing water consumption vary across cities because the factors of domestic water usage are deeply complex and differ from place to place (Fan, Gai, Tong & Li, 2017). As an example, the city of Melbourne managed to reduce their water consumption by 57 percent through education programs and public awareness campaigns (Bryx & Bromberg, 2009). While California, USA, could only see a reduction of less than 20 percent, despite having implemented the same strategies (Renwick & Green, 2000). Accordingly, it is fundamental to determine the domestic factors influencing water consumption in order to lay the foundation of effective water resource management with related public guidelines at a national scale. In Sweden, it is found that installing individual hot water meters and imposing a price of consumption have the potential of reducing hot water consumption by 15 to 30 percent (Swedish Energy Agency, 1999). Though, the costs of installing water meters are often too high to be profitable for buildings with a low to normal water consumption (Boverket, 2008; Swedish Energy Agency, 1999).

In a study of the water usage in different areas in Gothenburg, the citizens with the lowest income had the highest water consumption (Mahmoudi, 2017). This goes against previous findings that a higher income results in a higher water consumption (EEA, 2013). Though, this likely a result of the relatively high number of children and youths in the low average income group, and that parents to new born children up to two years old are more at home due to parental leave. Furthermore, Mahmoudi (2017) found that residential water consumption decreased as the temperatures increased. Possibly because the residents choose to go outside when it gets warmer. Though, it is necessary to realise that people use water everywhere, a lower usage of water in one area might be because people use it in another area (Mahmoudi, 2017).

3.4 Gamification

Gamification is a relatively new subject, thus, there is not a standard definition yet. One definition is that gamification is "the use of game design elements in non-game contexts" (Deterding, Sicart, Nacke, O'Hara & Dixon, 2011). This definition does not include what the objective with gamification is. Another definition is that gamification is "a process of enhancing a service with affordances for gameful experiences in order to support users' overall value creation" (Huotari & Hamari, 2012). This definition emphasises that game elements, here denoted as affordances for gameful experiences, may improve the user experience and results. Furthermore, it highlights that gamification should encourage the value creation of the user.

The purpose of gamification is to stimulate users to attain certain behavioural or psychological outcomes. An additional motive is to increase the users' engagement, satisfaction and loyalty. The outcomes can vary from learn faster, complete personal profiles or to use a product or platform on a daily basis (Deterding et al., 2011). Moreover, gamification enables the influence of user behaviour without the utilisation of extrinsic incentives such as monetary prices or punishments (Gnauk, Dannecker & Hahmann, 2012)

Studies have shown that gamification, and the game mechanics included, have a striking effect on motivation and participation in a non-playful context (Gnauk et al., 2012; Yang, Ackerman & Adamic; 2011, March; Herzig, Strahringer & Ameling, 2012; Thom, Millen & DiMicc, 2012). Particularly, the unexpressed factors such as joy, comfort of use, workflow and perceived functionality can be directly improved (Matallaoui, Hanner & Zarnekow, 2017). One of the benefits of using 'gamified' systems is the easy access to user data on diverse experiences. Moreover, it naturally gives rise to experience categories that emerge from interactions with these systems (Deterding et al., 2011).

User experience is a term that is important to recognise to understand how users' motivation and engagement can be affected. User experience, defined as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service" (Law, Roto, Hassenzahl, Vermeeren & Kort, 2009), significantly influences the motivation of users. Therefore, a system must not only be perceived as useful or easy to use, but also entertaining and stimulating, in order to have a positive effect on the engagement of the users. This is important for engaging users in the long term (Gnauk et al., 2012)

In order to understand the game concept, how to successfully design a game and succeed with gamification in general, there are several features that needs to be included. In accordance with McGonigal (2011) these include: Clearly defined goals providing purpose for the players of the game; consistently defined rules which represents the limitations and boundaries of reaching the specified goals; a persistent feedback system assuring the players that the goals are achievable, given that game rules are respected; and the free will of accepting engagement in the game, consequently following its rules to reach the goals (McGonigal, 2011). Indubitably there are numerous games that come with various other features such as interactivity, storytelling or rewarding systems, to name a few. These features are only further developments and improvements of the elementary features (Deterding et.al. 2011).

To create an engaging experience with gamification, a close alignment of the game mechanisms, emotions, dynamics and rewards that the users value or crave are needed (Robson, Plangger, Kietzmann, McCarthy & Pitt, 2016). The basic building blocks of a gamified system are the game design elements (Deterding et al., 2011; Werbach & Hunter, 2012). Werbach and Hunter (2012) identified 15 of these game design elements, including among others, leaderboards, badges, points and teams. What they consider the characteristic of gamified applications are what they call the 'PBL triad', the interplay between points, badges and leaderboards. Furthermore, they identified ten game mechanics which are the processes that generate engagement and drive the action forward. These include: challenges, chance, competition, cooperation, feedback, resource acquisition, rewards, transactions, turns and win states (Werbach & Hunter, 2012). Badges, leaderboards and performance graphs positively influence the users' competence-need satisfaction and perceived task meaningfulness. Avatars, meaningful stories and teammates positively affect the experiences of social belonging (Sailer, Hense, Mayr, & Mandl, 2017).

4. Results and Analysis

The aim of the chapter is to present and analyse the market of electricity and water in Sweden and the gathered qualitative and quantitative data. The first part of the chapter presents the market analysis in which pricing models of electricity and water are presented, followed by products and services that aim to lower electricity- or water consumption. The second part is qualitative and starts with a qualitative analysis of consumption behaviour and habits of residents. This is followed by an analysis of interviews with experts within housing and energy management. The third part of the chapter consists of the quantitative data and analysis. First, the results of the regression analysis of electricity consumption is presented and then analysed. Lastly, water consumption and the effects of installing individual metering and billing is presented.

4.1 Market Analysis

This chapter aims to describe what the market for electricity and water looks like in Sweden. It starts with presenting price models for electricity and water followed by an overview of products and services available on the market, that aims to lower electricity- or water consumption.

4.1.1 Metering in Sweden and other countries

Including electricity and water in the rent seem to not be apparent in all countries in Europe but is common in Sweden. In Germany and Switzerland, the heating costs for households have long since been allocated the individual apartments, based on metering data. Several other European countries such as France, Austria, Spain and Denmark, began already in the 1990s in setting requirements for individual metering and billing in newly built apartments. Sweden has, since the 1980s, negatively regarded individual metering and billing of heat and hot water due to the non-apparent economical feasibility (Swedish Energy Agency, 1999). In the directive (EU) 2018/2002 there is a requirement of installing individual metering of heat and hot water in multi-apartments. “Individual meters shall be installed to measure the consumption of heating, cooling or domestic hot water for each building unit, where technically feasible and cost effective in terms of being proportionate in relation to the potential energy savings” (Directive, 2018). It is questionable why the housing companies of Sweden are so sceptical of individual metering and billing when many other European countries have been using it for a long time. The Swedish Energy Agency (1999) argued that with the forthcoming of IT infrastructure and metering technology development, it would be more profitable to implement individual metering and billing. However, Sigglesten and Olander (2013) found that it was still a very low diffusion of individual metering and billing of heat and hot water in Sweden where housing companies are strongly opposed to installing these meters. This opposition seems to be the lack of finding cost-efficiency in the systems and the administrative inconvenience (Boverket, 2008). The situation seems to be the same today as it was in year 1999. Technology is still too expensive and the administrative costs of implementing individual metering and billing technology are too high for housing companies in Sweden.

Yohanis et al., (2008) found that for residents in Northern Ireland, privately owned homes consumed more electricity than rented homes that did not have electricity included in the rent. This was thought to be due to owners of private homes having a higher income than people renting their homes. In contrast, Ndiaye and Gabriel (2011) found that in Canada, rented homes displayed a higher consumption than privately owned homes, here thought to be because utilities most often were included in the rent.

This fact makes it problematic for housing companies to introduce consumption reduction policies in Sweden since the renting structure on including utilities in the rent varies amongst housing providers. Tentatively, no utilities are included in the rent, incentivising residents to consume less electricity and water and paying for what they consume. At the same time, this can influence the prosperity of low-income takers having to constrict their electricity consumption and widen the gap between high- and low-income takers. In conclusion, income is a powerful indicator on relative electricity consumption.

4.1.2 Pricing models

There are several different methods for pricing consumption of water and electricity. Since electricity cannot be stored in the grid, it is consumed as it is produced. The volatility of electricity consumption and all its inherent factors influencing supply and demand, therefore, influence the spot price of electricity (Faruqui, 2010). In conclusion, this means that the price is dynamic and influenced by supply, demand and by real-time factors (RWE AG, 2019).

The supply is influenced by the generation potential that can vary depending on the time of day and weather for solar panels, wind turbines and hydroelectric generators; current fuel prices and CO_2-emission prices; as well as a multitude of other factors. Demand, on the other hand, depend on consumer behaviour which can be broken down into factors - among others - time of day, possible holidays, trends, the global economy, etc., and factors that are not yet understood (RWE AG, 2019). The factors influencing the price of electricity can be conceptualised in fig 1. by the following schematic:

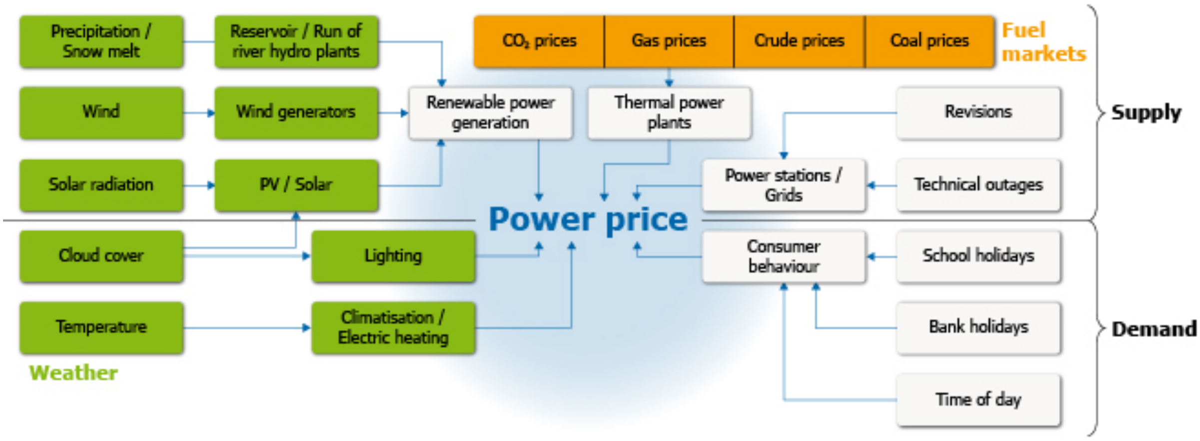

Figure 1: Factors influencing the spot price of electricity. Source: RWE AG.

Different electricity providers offer different price models. Usually, companies offer several price models for customers to find the best fit for their budget or consumption. One of the biggest providers of electricity in Gothenburg, Göta Energi, offers three different pricing models for their customers. Alternative one includes a set electricity price during the winter months and dynamic pricing for the remaining months. Alternative two includes dynamic pricing for all months where Göta Energi sells the electricity for cost price, and alternative three includes a set electricity price for the next 18 months. Common for all alternatives is that there is an additional fee for being connected to their powerline (Göta Energi AB, 2019). Some residence providers include electricity in the price of rent. This is the case for Company X, though, they implemented individual metering and billing to individually measure electricity and water consumption in two areas year 2015. If electricity- and water consumption exceeded a set amount, depending on the size of the apartment, the resident payed a higher set price and if not, they payed a lower set amount. This set amount was also decided based on the size of the apartment (Expert 2, 2019).

Water is priced quite similar to the electricity pricing in Gothenburg. There is a fixed cost related to being connected to the water pipeline, and a variable cost related to how much water is consumed. The cost varies depending on what kind of house it is, e.g. villa or apartment complex, how big it is, and how big the plot is (Göteborg Stad, 2019). Some residents have water and electricity consumption included in their rent and some residents have water included in the rent but not electricity.

4.1.3 Products and services lowering electricity- and water consumption

To understand what solutions are available on the market that aim to lower electricity- and water consumption, a market scan of products and services was performed. The search for products and services was mainly performed using Google's search feature or by searching online electronics stores with the search words: electricity reduction products/services, water reduction products/services, smart energy products/services, smart water products/services, energy efficient products/services and water efficient products/services. The products or services that was looked for had to satisfy the criteria that the product's or service's aim is to lower electricity- or water consumption, or to facilitate the management of products that can be used to reduce electricity- or water consumption. Furthermore, the expert interviews, which are presented in the following subchapter, provided insights on some solutions that have had a positive effect of reducing electricity- or water consumption, which are included in the tables. To find emerging solutions that are not produced in full scale, the same search was also performed at Kickstarter, which is the world's largest crowdfunding platform for creative projects. The purpose of scanning the market of products or services is to understand what residents can do themselves and what housing companies can, or even should, be responsible for in order to lower electricity- or water consumption. The solutions were categorised into different application areas and functions which are presented in Table 1 and Table 2. The products or services have not been tested to measure the actual effectiveness.

Table 1: Water saving products and services

Water Saving	Products	Controllable	Controlled manually	- Water Heater - Taps - Shower heads
		Water Tracking or Measuring		- Water meter
		Hardware		- Low flow shower heads - Dual flush toilets - Low flow taps - Low flow device to put on taps - Water efficient white goods
	Services	Water Tracking		- Invoices - Rent - Water meter
		Renovation		- Pipes - Water flow in buildings
		Maintenance		- Seal leakages

Table 2: Energy saving products and services

Electricity Saving	Products	Controllable	Controlled by remotes	- Socket switches - Thermostats
			Controlled manually	- Socket switches (on/off) - Socket timers - Radiator valves - Thermostats
			Controlled by applications	- Radiator valves - Lightning control - Socket switches - Smart thermostats
		Electricity Tracking or Measuring		- Electricity meters - Sockets - Smart plugs
		Hardware		- Light bulbs - Energy efficient white goods and other electronics
	Services	Energy Tracking	Applications	- Greenely - Energikalkylen
			Invoices	- Electricity bill - Rent
		Renovation		- Windows - Facade - Ventilation - Isolation
		Maintenance		- Heating - Isolation - Ventilation

Table 1 and Table 2 show that there are more solutions on the market that can reduce electricity consumption than water consumption. There are no services that residents can use themselves that aims to lower residential water consumption. Rather, they track water consumption, and provide information on how much water the residents have consumed with invoices or with the rent bill, given that the residents have a water meter installed. The other services related to water are regarding continuous maintenance or renovation work provided by housing companies. To reduce water consumption, there are more hardware products that reduce consumption when drawing water. Therefore, no behaviour needs to change in order for a resident to lower consumption if these products are installed.

While for electricity, the products must mainly be controlled either by remotes, applications or physically through an action of the resident in order to lower electricity consumption. These require a change in behaviour for the resident, they will need to start using an application, manually or remotely turning on or off a socket switch etc. If the main purpose of the applications, switches and remotes are to make it easier to turn off a socket or light, it will also be easier to turn them on. However, if the resident has all sockets on by default, this solution will influence consumption behaviour and decrease electricity consumption. There are other ‘smart solutions’ such as temperature optimising and thermostats that analyse the indoor temperature and optimise the heating. Instead of always having radiators on max, making it too hot inside and cooling the room down by opening windows to ventilate, the temperature is optimised for the climate inside. Lowering the indoor temperature by one degree Celsius, corresponds to a five to six percent decrease in heat demand (Swedish Energy Agency, 1999). With smart thermostats it is possible to achieve an energy reduction of 28 percent on average (Lu, et al., 2010). Services that can reduce unnecessary electricity consumption are mostly related to maintenance and renovation.

Water consumption can be reduced by replacing, among other, older toilets, white goods, shower heads and taps with more water efficient products. This is also likely to reduce the electricity consumption as more water efficient products mean less water needing to be heated. A water meter is the easiest way of knowing the exact water consumption and works as an incentive for residents to use water more wisely. The responsibilities of providing these devices in multi-apartment buildings would mainly be the housing companies’ as they have the best opportunity of buying and installing them. In cases where the residents renovate their apartment or replace devices themselves the responsibility should lie with them or with the tenant. For people not living in apartments, the responsibility of installing these devices lie solely with them.

On the electricity side, there are more solutions that relates to smaller devices that can be used to facilitate the management of electronic devices, switches, remotes, applications etc. These are not considered a responsibility for housing companies to provide but rather an opportunity for the residents. Nevertheless, housing companies should always provide energy efficient lightning and electronics for the building and residents are responsible for providing this for their homes. However, if the residents’ electricity is included in the rent there are no incentives for them to lower their consumption. It is not believed that they will use these devices in order to lower electricity consumption but rather for convenience, if used at all. For residents that have their own electricity agreement, there are services that can be used to easily get an understandable overview of the electricity consumption. Though, the residents must sign up to the services themselves. If residents do so, they can attain a greater knowledge of their consumption which, in turn, will increase the chances of changing behaviour to decrease their electricity consumption.

If residents live in rented apartments, the housing company provides services regarding maintenance and renovation, both regarding electricity and water. Although, residents should have the responsibility of reporting to the housing company if any anomalies occur in their home, such as leaking windows, toilets or faucets, so that these can be fixed as soon as possible. A lightly dripping faucet consumes almost 100 liters of water each day (Vattenfall, 2018). For a housing company that has hundreds of apartments, these volumes can quickly escalate if not dealt with. For residents living in houses the responsibilities are solely their own.

4.1.2.1 Greenely

Greenely is a Swedish company, based in Stockholm, that provides an application that aims to get their users to lower their electricity consumption. The service was launched in the spring year 2017 and currently has approximately 45 000 users. Signing up to the services is free and the user fills in the characteristics of their household and signs a power of attorney to Greenely, that allows them to gather the user's electricity data from the power grid. The service lets you see your electricity consumption hourly and summarises your weekly and monthly consumption, which you can compare with yourself and other similar households. The application shows, in percentage, during what hours of the day you consume the most electricity. It also provides electricity saving tips and explanations of how to interpret your electricity invoice, for instance. Greenely have cooperated with Stanford University for a long time to develop and test new functions with the basis of behavioural science. Currently, they are conducting a pilot project in California to judge the impact of the service.

Last year, Greenely investigated how the electricity consumption had changed after signing up to the service. What they found was that residents living in villas and townhouses, had on an aggregated level reduced their consumption with 6,3 percent, even if households generally increase their electricity consumption over time. For residents living in apartments, no significant trend of reduced consumption could be seen. What they have noticed is that users seem more dedicated in reducing their electricity consumption the period shortly after signing up to the service. In the longer run the consumption seems to fall back to normal levels. However, some users are engaged in the service and, among other things, contacts Greenely to explain their behaviour or what they have learnt (Fredrik Hagblom, personal communication, February 22, 2019). With a reduction of 6,3 percent, it would be possible to reduce the consumption of fossil fuels by 6,3 percentage points, but the more realistic scenario would be a reduction of all electricity sources by 6,3 percent, including fossil fuels.

The service is gamified in some ways as you can compare your consumption with your own consumption the previous weeks, months and years but also with similar households' consumption. The feedback that Greenely provides for its users are historic comparisons, but they do not include presentations of aggregated costs or appliance-specific breakdown, which together are perceived as most important. As Greenely only presents the total hourly electricity consumption, the user itself must remember what appliances they used during those hours to evaluate their electricity consumption. Devices usually have a label that shows the power the device uses. If a device is rated to consume 400W of power, and it is operated for one hour at that level, it sustains 400Wh of energy. To include appliance-specific feedback in the service in some way, can make the users better at understanding the impact their behaviour has on electricity consumption. Furthermore, the users aggregated electricity costs are not included in the service and users must, therefore, check their electricity invoice to know what their consumption costs monetary. Moreover, it is found that the most effective feedback types in reducing electricity consumption are direct feedback by itself or in combination with other feedback types. Greenely provides the electricity consumption hourly, not in real-time but the day after, which is greatly more direct and frequent than receiving an invoice once a month but not as direct as reading a self-meter. Although, it is likely that the users know roughly what appliances they used during what hours of the previous day, educating themselves in their electricity consumption.

The engagement of the users seems to be there initially but decreases after a while. Therefore, the service is probably perceived as useful and easy to use, but lacks the entertaining and stimulating features, which are found to be important in having long term engaged users. Greenely seems to have a bigger impact on the behaviour of the users that live in villas or townhouses than users living in apartments. This might be a result of villa and townhouse owners generally having higher electricity expenditures and expecting a higher monetary gain than people living in apartments. The service, as it is today, incorporates some game mechanics, although not enough to be completely gamified. Additional game design elements, such as leaderboards, badges, points and teams together with game mechanics such as challenges, competition and rewards, will likely increase the user satisfaction and engagement. Moreover, adding other ways of engaging people in Greneely's service would be a promising way of affecting residents' electricity consumption behaviour. Today, not all residences have individual metering technology installed which means that not all residents can participate. Since they do not have access to their consumption data it is impossible for them visualise their own consumption behaviour which, in turn, make it harder for them to understand their own consumption behaviour.

4.2 Qualitative analysis

The Expert interviews section starts with describing and analysing how gamification helped lowering the electricity consumption by 2,5 percent in an entire city. This is followed by presentation and analysis of what the companies of Expert 2 and 3 do to further sustainable living and their experiences with individual metering and billing. The residents chapter aggregates residence sustainability behavior, residence sustainability aspirations, and residence knowledge of their electricity and water consumption.

4.2.1 Expert Interviews

Expert 1 is currently working at CGI as an innovation manager. He has worked as a project manager with several projects including gamification. The projects have been in different contexts, of experimental character but also in the development of new services that are used today. The interview focused on a project that the Expert worked on where the aim was to lower electricity consumption in Växjö, Sweden.

Expert 2 works as the energy director of a big housing company (Company X) that is owned by the municipality of Gothenburg. His previous experiences include being the vice president and technology manager of a service provider for property managers for ten years. Some of his responsibilities at Company X include aspiring to meet the public energy goals, making strategic decisions regarding energy and attending energy council meetings with Boverket, a Swedish property authority. He considers the housing industry as conservative and states that change takes time but is vital.

Expert 3 works at Chalmers Student Bostäder, CSB, a student housing company in Gothenburg that currently offers 2240 apartments to students at Chalmers University of Technology and the University of Gothenburg. He has worked within property management for several years, including administrative work, development of housing services and as property manager in charge. The last nine years he has worked at CSB.

4.2.2.1 Lowering electricity consumption through gamification

When developing gamification, Expert 1 uses Bart's gaming types to categorize people's' aims and behaviour when they play. One type is Achievers who like to compete and be in the leading positions. Socialisers are those who most often posts things, on Facebook for instance. Explorers are those who want to explore and Killers are those who want to show that they can break the rules in smart ways (Expert 1). All these gaming types need to be thought of when creating a gamified system and all of them should be able to get to the top. "What many do wrong is that they create a competition where only one can reach the top and then companies believe that they have gamified the service or product, but it doesn't work." (Expert 1). Given this, it is important to develop the gamified system so that all types of people can reach the top, not only the most competitive people. If the goal is to get people to use and stay in the service "It's incredibly important to understand your users. [...] You should be aware of what you want to achieve, an important part is to control behaviour and steer towards these." (Expert 1). Therefore, if users' electricity consumption should be lowered with the use of a gamified system, the users' behaviour must be understood to be able to steer them into consuming less electricity.

As it is shown that direct feedback and high qualitative feedback lowers, this type of feedback is recommended to be included in the gamified system. Furthermore, you must challenge the users so that they are steered into certain behaviours. "In gamification you get smaller challenges which all the time makes you better. It's the behaviours you steer not the result." (Expert 1). The highest likeliness to change behaviour is to confront motivation/intent, ability and opportunity at the same time. Thus, the gamified system should be developed such that when the user completes a challenge, they are acknowledged for displaying the desired behaviour. These acknowledgements motivate the user to use their ability to change their behaviour in these specific situations.

Expert 1 briefly explained the project and his role as follows:

> *"We lowered the electricity consumption by 2.5 percent throughout the whole of Växjö city. We measured everything and during several years. At that time there wasn't even gamification as a concept. We had some researchers from Interactive Institute, current RISE,*

and used 'Persuasive gaming' to influence people and their way of being. [...] I was hired by the municipality and it was an EU-project which we conducted together with property companies, energy companies and the municipality." (Expert 1)

They managed to lower the electricity consumption by 2,5 percent throughout the entirety of Växjö and they "solely built it on communication with people and understanding their behaviour." (Expert 1). Their solution was to provide the mechanism for the users to think that electricity consumption is a fun topic and make them engaged in it. "People know what they should do, but you need to give them the mechanism to find their interest in doing so. People know that they should turn off the lamp when they leave a room, but by awakening the engagement you can actually make it fun to turn off the lamp. [...] we had about 40 000 measuring points, so it was hard to know exactly what was what." (Expert 1). Even though it was sometimes hard to know what effects could be derived to what actions due to the many measuring points, they engaged the residents by incorporating a visualisation of their electricity consumption which was given to the residents in paper form. "Humans are not just interested in energy saving tips, that's not how it works. We built visualization things and similar so that the people could see their energy consumption." (Expert 1). If a 2,5 percent reduction in electricity consumption was realised with the right communication and visualisation, it is expected that an even bigger reduction would be realised if these are incorporated in a gamified system with today's use of smartphones and applications.

If the goal is to lower residential electricity consumption, the solution must not only be interesting and engaging to use. The solution must be diffused to reach out to people that can start using it. "One has to create solutions that are interesting to use. But it's a giant threshold to get people to use it. [...] you can always buy your way to reach out to people but to engage people is not that easy." (Expert 1). Thus, it is not enough to have an interesting and engaging solution or to reach out to a large number of people, they both need to be realised. Expert 1 seems convinced that you can buy your way to reach out to users through marketing but even with a lot of marketing it is a challenge to engage everyone. "We could see a clear difference, some people just don't care and are unreachable. But we did reach out to some that we really had an impact on." (Expert 1). During the time of this project, smartphones and the associated applications barely existed. It would be interesting to see the results a similar project would have today with the use of smartphones and the more easily accessible consumption data.

Perhaps the ‘unreachable’ people are reached out to through online marketing on social media and not by the more traditionally marketing methods, such as TV, newspaper and radio.

Gamification can influence user behaviour without extrinsic incentives, However, by having extrinsic incentives one can foster extreme behavioural changes. One, of many, competitions among the residents of Växjö was that the home which had lowered their consumption the most, won one month’s rent. By doing this, they “got some extreme behaviours and even if it’s not sustainable in the long-term you realise that you can do better than you think.” (Expert 1). This shows that by having monetary prizes people are willing to change behaviour to a great extent. The extreme behaviours are not sustained in the long run, people still need to use electricity to perform many of the daily tasks in their homes and to have a certain level of comfort. Although, these competitions can make residents understand, and evaluate themselves, what they need and what can actually be reduced, and that it might not be as hard to reduce their consumption as first thought. Even if they had monetary prizes, Expert 3 said that “It wasn’t really about rewarding the winner but to increase the knowledge about energy consumption and to get people experimenting. We noticed that people started to talk about it with other people, and that’s what we wanted to achieve.” (Expert 1). Given the results of the project in Växjö, residential electricity reduction is likely to happen in other cities with similar, if not better, results. Today, more direct and higher quality feedback of electricity data is available, which is an important part in changing behaviour. If a change in behaviour is to be realised for the society as a whole, the existing systems and institutions cannot remain the same. Therefore, a joint effort from all parts of the society including the municipality, housing companies and residents is needed to change the structure. All parties must start talking more about consumption reduction to make people realise what impact their consumption has and, maybe most importantly, start acting on it.

4.2.2.2 Individual metering and billing

When asked what data the experts’ companies gather and how they use it, both experts state that they measure temperature in apartments. Temperature data is used by Company X to “work with day-to-day optimisation and analysis of heating systems and heat problems.” (Expert 2). The same goes for CSB which they “use to cope with the heat consumption in particular.” (Expert 3).

When asked more specifically about individual metering and billing data, Expert 2 answered that they, at Company X, gather individual consumption data of electricity and water in newly built apartments, where they install individual metering and billing technology. Company X also gathers consumption data in pilot areas. Two of these pilot areas were terminated because they "saw that those two projects didn't live up to the investments. [...] The operating costs are too expensive to find profitability in those systems." (Expert 2). Even if the reason for terminating the pilot projects seems to be the economic aspect, it can be traced back to the well-being of Company X's residents, as all profits are reinvested in the properties. About individual metering and billing, Expert 3 said that "It doesn't work with individual metering and to pay for what you consume, it has been tested so many times, but it doesn't work." (Expert 3). After years of trying individual metering and billing, Expert 3 is convinced that it does not work to lower consumption. One time it did work "but the electricity consumption was only lowered to normal consumption levels." (Expert 3).

At CSB, the electricity- and water consumption is measured at a building level and not at an individual level. In apartments where individual metering and billing are already installed, they "will not maintain the individual metering and billing systems or take out the data measurements from them any longer" (Expert 3). The reasons for not taking out the data measurements are because *"*it has been huge administrative costs related to this. [...] there are reasons why we have electricity companies that are familiar with electricity management and maintenance" (Expert 3). Because of the administrative costs related to individual metering and billing of electricity, Expert 3 believes that electricity providers should handle it. If electricity providers were to be responsible for this, it would imply that the housing companies are to not include electricity in the rent at all, or that electricity providers would supply the maintenance and administration of individual metering and billing as a service. As Expert 3 seems utterly convinced that individual metering and billing does not work, it has probably strengthened the decision to not continue metering apartments which already have individual metering and billing technology installed at CSB. Using the already installed individual metering and billing technology for longer or to a higher extent would bring down the operating- and administrative costs due to the presence of a learning curve, a fact that seems to be disregarded by both companies. Moreover, adopting metering technology would incentivise developers' technology innovation.

Both Expert 2 and 3 seem to believe that individual metering and billing does not work. Although, if they want the residents to change behaviour, it is not sufficient to only provide informative instruments. The companies provide the electricity- and water consumption on the invoice or at their websites, which is only informative instruments. As they do not provide any other tools for the residents to visualise, understand, or influence them, they cannot expect a change in behaviour. This results in the perception that individual metering and billing "does not work". Housing companies must understand that installing individual metering and billing might not on its own change the behaviour of the residents to lower their electricity- and water consumption. The residents need steering and motivation to actively change their behaviour. If this should be provided by the housing companies, private companies, government or society as a whole, needs to be further investigated.

Expert 2 and 3 both mention the high administrative- and operational costs of collecting data with individual metering and billing technology. A solution to this can be to let all resident have their own electricity agreements. If residents have their own electricity agreement, the housing companies will reduce their administrative and operational costs of taking out the individual metering and billing data. The residents will pay for the electricity they consume directly to their electricity provider, and they can ascertain their electricity consumption. At the moment, residents living in apartments that do not have individual metering and billing are not able to see how much they consume. One of the reasons that housing companies stand on the electricity agreements is that it allows all people, despite their conditions, to be provided with electricity. Explained by Expert 3: "CSB stands on the electricity contracts and it would not be an advantage for students to note their own electricity agreement. It would be problematic as students live quick lives with many changes and it might be that they cannot economically stand on electricity contracts." (Expert 3). If the high administrative and operational cost were to decrease, by either using better metering technology, outsourcing, or by educating residents in what their behaviour cause in their consumption, housing companies are more likely to provide individual metering and billing with an economic profit.

As it is shown that visualisation of electricity consumption has the potential of reducing it by up to 55 percent. Providing easily available and descriptive consumption data is an important component of resident consumption reduction. Therefore, providing individual metering and billing internally, by housing companies or externally, by electricity companies, is considered a highly important part of reducing residential electricity consumption.

4.2.2.3 Electricity- and water reduction initiatives

When asked whether the companies have tried any initiatives in order to lower their residents' electricity- or water consumption, Company X "focus on the properties and things that do not affect the residents directly. [...] focus on water and swap all taps in the kitchen, washing sinks and showers etc. to minimise water usage in these areas. Small initiative, but it works very well." (Expert 2). To lower electricity consumption, Company X performs "a lot of continuous operations that lower the energy consumption. FTX-recycling in the ventilation, in these projects we also swap windows and facade which saves a lot of energy. We have seen almost a halving of energy consumption after a facade, window and ventilation swap." (Expert 2). FTX is a fan-controlled supply and exhaust air system with heat recovery. The heat passes a heat recovery unit that uses the energy in the exhaust air to heat the cold incoming air, saving energy but also giving a better indoor air. Company X's initiatives to lower electricity- and water consumption is not regarding changing the behaviour of the residents but rather making upgrades or using gadgets that lower the consumption. This does not require any effort from the residents but will reduce the electricity- and water consumption given that residents do not change their behaviour. Although, when they choose to not interfere with their residents, they cannot expect their residents to automatically change their consumption behaviour and consume less.

While for CSB, "The big investment was the individual metering that began in 2006, and then we have pushed the work forward to broaden it, but it was more wasteful to continue with it than to wind up." (Expert 3). Expert 3 does not mention any other initiatives to lower the residents' electricity and water consumption. Although, "The biggest thing we have done for reducing consumption is without the participation of the residents, for example smart heat. [...] the biggest culprit is that we ventilate away the heat." (Expert 3). What CSB has done to reduce household consumption is mostly at a level that residents do not notice, as it is without the participation of them. It seems like CSB has noticed that the ventilation and climate in apartments affects the energy consumption. To cope with this, CSB uses carbon filter fans over the stoves instead of only ventilation. "as we filter the air instead of only ventilating it away, we have reduced the circulation with about a third, which we also have noticed on the energy consumption." (Expert 3). CSB has found a way of lowering the amount of heat that is ventilated away by installing carbon filters over the stove. By doing this they succeeded with lowering energy consumption, to what extent is not mentioned though. This is, additionally, something that housing companies and private residents can do in order to lower the electricity consumption.

When Expert 3 answered what other initiatives he believes can lower consumption, he reasons that the costs of using water should be reconsidered and include penalties for higher water consumptions than a standard. “You realise that it doesn’t cost much to have a higher consumption. [...] You need another sort of billing and to introduce some penalty for over-consumption.” (Expert 3). As it is now, Expert 3 seems to believe that there are no economic incentives to lower your water consumption when you barely save any money on it. He does not mention where limits of over-consumption should be or how the pricing model should change. Nevertheless, if a lower water consumption is a priority in Sweden and the current water prices are too low for people to care about their consumption, the government should review the water price structure and increase the price. Although, what a reasonable water price structure should be and if there should be penalties for over-consumption needs to be further researched. However, for housing companies, a water reduction can be realised by introducing individual metering and billing if the residents do not pay for their water consumption at the moment. Even if the consumption for one resident is only lowered with some percentages, the accumulated savings of all residents together make a bigger positive effect. Further, what is important to notice is that leakages can result in extreme costs of water consumption, but if a resident cannot access their water consumption, because it is included in the rent, these leaking costs only end up for the housing companies. It might also be hard to find where the leaks are, resulting in accumulating water costs, but also electricity cost if it is hot water that leaks for the housing companies.

CSB wants their residents to lower their consumption “We want to reduce the individual consumption, so we have to focus on that” (Expert 3). Although, he does not think that CSB as a company can have a greater impact on the residents’ behaviours as the world looks today. “Our influence on the behaviour of residents, I believe, is quite limited, we live in a soft world where we don’t force someone to do something. But in an upcoming crisis that is increasing in probability, it will be required that you are not as soft in order to bring about changes.” (Expert 3). It seems like Expert 3 thinks that they cannot influence the residents’ behaviour being as soft as they are today and that stricter rules are needed in order to influence behaviour. Therefore, stricter rules from government might be what housing companies need to be able to put pressure on their residents. If all people do not pay exactly for what they consume it can be hard for the government to introduce an electricity- and water consumption price model that is applicable for all. Otherwise, this price model might be that a consumption over certain levels leads to higher prices for the electricity- or water consumed above the levels, which can be a powerful EPI implemented by the government. This can incentivise people to think of, and lower their, consumption as it is better economically for the individual.

Expert 3 said: “I believe that property owners must be those who drive and introduce energy-efficient products. [...] many products don’t work, and you have to be incredibly observant when looking at new technology”. (Expert 3). While Expert 3 believes that housing companies must be the ones who drive and introduce energy-efficient products, it rather seems like they are late adopters of technology. He seems sceptical of how well these energy-efficient products work and it seems like they are waiting for technology to be better before they introduce it to their buildings or apartments. Similar was said by Expert 2 about individual metering and billing technology, “I do, however, expect development to be quick. [...] When the technology is cheaper, we can look into these options again.” (Expert 2). Given this, it seems like housing companies are late adopters of new technology within electricity- and/or water metering and saving devices.

Another sustainability initiative by Company X was the installation of solar panels, which has reduced the ratio between the electricity they buy and the electricity they produce themselves. “Already, we manage to use 60 percent of produced electricity and 40 percent is distributed to the electricity grid.” (Expert 2). While installing solar panels is not an initiative to reduce electricity consumption, it works as a driver for using renewable energy to a higher degree, which furthers the reduction of fossil fuel usage which, in turn, is the goal with reducing electricity consumption. Even if Company X’s residents cannot utilise all the produced electricity, the remainder is distributed to the grid. This provides some extra revenue but most importantly increase the use of renewable electricity for others as well.

CSB sets long term targets on energy consumption. ”On our internal goal, we have looked at how much energy we consume per square meter. [...] the measure we use internally is total purchased energy, which is the facility electricity, household electricity, and heating.” (Expert 3). The targets measure total- but not individual energy savings. Using this measure, they could significantly lower their total energy consumption by building new apartments using existing systems. “One of the biggest energy savings we have done was to build new apartments that used the existing systems, which improves the result of energy usage per apartment in kWh/m^2.” (Expert 3). In Annex I the total consumption of electricity and heating in kWh/m^2 at CSB from January 2007 to January 2018 can be seen.

Furthermore, CSB have noticed that installations of radiators are not done correctly, which lowers the capacity. After they “reviewed all installed radiators in a newly built building and 30 percent were faultless [...] We have now included this in our building standards to get it right from the start.” (Expert 3). To ensure that unnecessary electricity is not consumed due to errors in installations. Information should be spread about this, and better education to people performing installations needs to be introduced. This can increase the probability that the installations are done correctly form the start, which would lower electricity consumption.

4.2.2 Resident Interviews

Seven interviews were held with people living in the municipality of Gothenburg, see Table 3 for some demographics of the interviewees. Full quotes from the interviews are presented in Appendix I.

Table 3: Demographics of the interviewed residents

Resident	Gender	Age	Occupation	Educational Status
1	Female	24	Student	University Student
2	Male	29	Working	University Degree
3	Male	25	Working	Upper Secondary School
4	Female	22	Working	Upper Secondary School
5	Male	63	Working	University Degree
6	Male	24	Student	University Student
7	Male	25	Working	Upper Secondary School

4.2.1.1 Behaviours and habits

When asked about what the residents do to live sustainable in their homes, almost all residents mentioned that they have started eating more vegetarian or vegan food and are buying more locally produced food. The residents also mention that they recycle, but to what extent they recycle varies among the residents. Some recycle everything all the time, while some recycle sporadically depending on how full the containers are or because of laziness. Five of the residents mentioned that they are somewhat thinking of their electricity usage as a way to be more sustainable in their home. The habits were to turn of lamps when leaving a room or not turning lamps on in daylight. Four of the residents mentioned behaviours concerning the use of less water. Three mentioned that they occasionally try to lower water consumption when showering and one mentioned reducing water consumption while doing dishes as well. Given the results, it seems like some people do not think of decreasing electricity-, and especially not water consumption as ways to be more sustainable in their home. Some residents try to think about their consumption but does not always behave according to what they think they should do. Only one of the residents mentioned behaviours performed at a habitual level to decrease electricity- and water consumption.

4.2.1.2 Aspirations

When the residents answered what they want to do in order to live sustainably, some of the residents mentioned behaviours that they had already changed, behaviours they want to attain, and some mention behaviours, but without intentions of attaining them. One of the already changed behaviours was not taking baths, despite the resident's expressed enjoyment of baths. A desired behaviour is to take shorter and colder showers, as one of the residents said:

"I try to lower the temperature of the water even though I like when it burns, but it's also because it's bad for the hair." (Resident 1)

Resident 1 associates the shorter and colder showers with sustainability. However, the reason for changing her behaviour regarding the length and temperature of the showers was not to live more sustainably but rather to protect her hair.

"I feel like it is a luxury to have water and then I feel that I enjoy it and consciously stay in the shower because I have the possibility. [...] actually you can just take shorter showers, I could change, but then I feel like a small part of my comfort decreases." (Resident 1)

The resident says that "you can just take shorter showers" and that she can change, but to say that you can change and to actually change your behaviour might not be as easy as it sounds. The perceived luxury of having access to water and being able to take long hot showers is one of the behaviours that needs to be influenced in order to lower energy- and water consumption.

Resident 5 mentioned that he would like to produce his own food. Although, it seems like he has an interest in gardening, which might be the primary reason for growing his own food and not for the sustainability aspect of it. Furthermore, the same resident answered that he believes that reducing energy consumption and driving less often are the most important factors to be more sustainable. Even though, he does not mention any intentions of lowering his own energy consumption or willingness to drive less often. He might still intend to do so, but it is not the same thing to say that it is important to lower energy consumption as actually lowering energy consumption.

"I want to be better at recycling, and not wash the dishes under running water in the sink. I want to inspire more people to not litter and live sustainable, [...] and make people feel like more than single drops in the ocean." (Resident 3)

Resident 3 knows that it is not sustainable to wash the dishes under running water but does so anyway. Doing dishes under running water is likely a habit arising from the unlimited access to running water and the perceived ease of doing dishes this way. It might also be due to small kitchen spaces or wanting the dishes clean straight away. However, for Resident 3, it seems like he thinks of inspiring others in living more sustainable as his principal way of making the world more sustainable overall.

"What I can do better is to take out chargers out of sockets when I leave home and not use all the electronics at the same time. Why I don't do it is fully based on laziness." (Resident 7)

Given Resident 7's answer, the obstacle to not improve his behaviour to reduce consumption is laziness. What he wants to improve is to remove chargers from sockets and not use that many electronics at the same time.

There seems to be a quite high level of knowledge about desired sustainability actions and behaviours. Though, the level of commitment does not seem as high as the knowledge of the residents. In some cases, there are other, more desirable, reasons or benefits of why they have or want to have a certain behaviour and in other cases they do not have a certain behaviour because of laziness or lack of feeling like what they do matter. What is important is to find how you can transform the knowledge the resident have into actions and behaviours that they always perform, without taking away the luxury, comfort and ease of doing things the way they do them today.

4.2.1.3 Knowledge of electricity- and water consumption

When the residents were asked of their knowledge of their electricity consumption, it was obvious that the residents did not have any knowledge of how much electricity they consumed. It did, though, seem like the residents had an indication of how much their electricity costs. As said by one resident:

"I can see my electricity consumption on the invoice, but I don't know how much I consume, only what it costs." (Resident 2)

It seems like residents measure their electricity consumption monetary and not in used kWh. A reason for this might be that it is hard to understand what 1 kWh is, and what it stands for, while they understand well what 1 SEK is. It was not any major differences in the residents' knowledge of their electricity consumption, regardless of them being the ones that signed the electricity agreement, having individual metering, or not having access to their electricity consumption at all. Those having access to the electricity invoice can look it up, but they do not do it on a regular basis more than when paying the invoice.

"I think that people should have better knowledge of their energy consumption, including myself, but how engaged do you have to be? I have to have time for my life as well." (Resident 3)

Resident 3 thinks that people, including himself, should have better knowledge of electricity consumption. Though, he seems to believe that it is time consuming to acquire that knowledge. It might be that he thinks that engaging in lowering his energy consumption is time consuming or takes a lot of effort. Looking up his electricity consumption is not a habit of his today and creating a habit of doing so might feel like too time consuming. If finding one's electricity consumption is already a habit, it does not require much effort and will not feel as time consuming. The challenge lies in presenting electricity consumption in a way that makes it more easily accessible and more engaging in order to minimise the barrier for starting the habit or changing the behaviour.

"I do not know my consumption. I've heard there is an app you can use to track it. [...]. Actually, I have no idea what things costs, like having the shower on for X minutes or turning

of the TV, how it changes. The environmental effects I have even less knowledge about" (Resident 7)

Resident 7 does not know what he consumes, neither electricity nor water. Although, he knows about the service Greenely, but does not actively use it. He does not know the costs of using electronic devices or taking a shower, and it seems to be even less knowledge about the environmental effects from it. To better improve the knowledge of what it costs to use devices he would probably find Greenely helpful as he can evaluate his electricity consumption to what devices he has used during that day.

When asked of their knowledge of water consumption, none of the residents know how much water they consume. One of the reasons for not knowing this is likely due to the absence of water metering. If any of the residents have individual water metering, their landlord has either not been communicating this or the communication has been overlooked by the resident. Since none of the residents know of their water consumption, or the fact that they might even have access to it, it is clear that this communication needs to improve, or even exist, in order to change water consumption behaviour.

4.3 Quantitative analysis

The quantitative analysis consists of a regression analysis of Greenely's electricity consumption data, an econometric analysis of the results of the regression analysis, an analysis of Company X residences' water consumption in two areas before and after implementing individual metering and billing, and the total aggregated water consumption of Company X's residents over the last six years.

4.3.1 Regression analysis of electricity consumption

A multiple linear regression analysis was performed in the program R in order to evaluate the model's ability to predict electricity consumption, using the 522 observations of electricity consumption over at least one year provided by Greenely. The data for each user of the application contained the number of occupants, 1 through 6 or more; surface area of the residence in square meters in an interval; construction year of the residence in an interval; used heating technology; and what municipality the user lives in. These are the predictor variables. The outcome variable of analysis, y_i, was the electricity consumption accumulated over one year before signing up to the application, the resulting unit of y_i being kWh/year for individual i. The model investigates how well the outcome variable can be predicted with the predictor variables and resulted in the following equation:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 x_{i3} + \beta_4 x_{i4} + \beta_5 x_{i5} + \beta_6 x_{i6} + \varepsilon_i$$

With the following variables:

- Municipality, (x_1)
- Facility surface area in square meters intervals, (x_2)
- Heating type, (x_3)
- Facility type, (x_4)
- Construction year intervals, (x_5)
- Number of occupants, (x_6)
- Electricity consumption in kWh/year, (y)
- Coefficients, (β)
- Error term, (ε)
- Observation/Individual, (i)

The model's output will be the coefficients, $\beta_{1\text{-}6}$, meaning the predicted influence every variable option has on electricity consumption. The intercept, β_0, is the predicted value of y when all the independent variables take on the factor value 0. For each observation/individual, $x_{1\text{-}6}$ will vary. x_{i1} denotes which municipality individual i lives in, x_{i2} denotes the surface area of the facility of individual i, x_{i3} denotes used heating type by individual i, x_{i4} denotes facility type of individual i, x_{i5} denotes the construction year of the facility of individual i and x_{i6} denotes the number of occupants of the facility. The dependent variable, y_i, can be predicted for each observation/individual, i, by knowing the independent variables, $x_{i1\text{-}6}$. If individual i lives in municipality x_{i1}, has a surface area of x_{i2}, uses heating type x_{i3}, has a facility of type x_{i4}, has a facility construction year of x_{i5} and has a number of occupants of x_{i6}, the predicted electricity consumption is y_i plus the error term ε_i, which is different for every individual, due to the model not being able to predict electricity consumption completely.

It was hypothesised that an increasing number of occupants, an increasing surface area, and an earlier construction year would predict a higher electricity consumption. It was also hypothesised that for heating types, using a boiler would predict a decreased consumption since it does not include the use of electricity, and using direct electricity would predict an increased electricity consumption since it exclusively uses electricity for heating. Municipality was hypothesised to have a non-significant predicting ability on electricity consumption.

To fit the model, the variables with data as a string or a number in an interval were transformed into categorical variables with each option being factors. These factors were named number wise depending on the number of different options for every variable. The number of occupants in every residence was transformed into a class since it linearly fit the multiple regression model. The following tables explains what variable options were given which factor number and the distribution of users for each variable:

Table 4. Factors assigned to each municipality in the dataset for the regression analysis.

Factor	Municipality	Distribution	Factor	Municipality	Distribution
0	Västerås	2	15	Malmö	1
1	Eslöv	2	16	Mjölby	13
2	Gävle	3	17	Motala	1
3	Göteborg	3	18	Nynäshamn	1
4	Helsingborg	1	19	Nässjö	19
5	Huddinge	1	20	Orust	1
6	Hylte	1	21	Sala	2
7	Jönköping	2	22	Sjöbo	1
8	Karlstad	446	23	Skövde	1
9	Klippan	1	24	Sollentuna	7
10	Kristianstad	1	25	Stockholm	1
11	Lerum	1	26	Sundsvall	2
12	Lidingö	1	27	Tranås	1
13	Linköping	2	28	Vaggeryd	1
14	Lund	3			

Table 5: Factors assigned to each residence size in a m^2 interval in the regression model.

Factor	Facility Surface Area (m^2)	Distribution
0	20-49	5
1	50-69	27
2	70-89	55
3	90-109	60
4	110-129	91
5	130-149	115
6	150-199	125
7	200-249	33
8	250-299	8
9	300 +	3

Table 6: Factors assigned to each heating type.

Factor	Heating type	Distribution
0	Boiler	12
1	District heating	271
2	Direct electricity	68
3	Heat pump	76
4	Geothermal heat pump	95

Table 7: Factors assigned to each residence type.

Factor	Residence type	Distribution
0	Villa	349
1	Apartment	103
2	Townhouse	70

Table 8: Factors assigned to each construction year in an interval.

Factor	Construction year	Number
0	Before 1930	42
1	1930–1960	77
2	1961–1975	135
3	1976–1990	114
4	1991–2009	30
5	2010–2019	21
	N/A	103

A significant multiple regression equation was found ($F(25.96, 48)=473$, $p<2.2e-16$) with a residual standard error of 3973 on 473 degrees of freedom, a multiple R^2 of 0.7249 and an adjusted R^2 of 0.697. Facility surface area factor 9 had a surprisingly low p-value which might suggest collinearity, this is thought to be between the number of occupants, facility type and facility surface area, under the assumption that bigger facilities can house more people and bigger facilities usually are villas. Though, this cannot be determined without testing.

Because of the complexity in using the variance inflation factor test on a model with categorical variables, the model was instead rerun to test for multicollinearity. First, excluding facility surface area, second, excluding occupants, and lastly, excluding facility type from the model. This resulted in three significant multiple regression equations with both facility surface area, for bigger surfaces, and occupants being significant predictors of electricity consumption. Facility surface area 9 had a similar p-value in the first, third and fourth model which might suggest collinearity with other dependent variables or between all three variables. The high p-value for facility surface area 9 can also be a product of the nature of the interval for this variable i.e. the theoretically infinite size. The hypothesis that occupants, facility surface area, and facility type are multicollinear cannot be discarded and there might be collinearity between other variables in the model. Since facility type was not a significant predicting variable, it was removed from the model to minimise the potential impact of multicollinearity. Table 9 summarises the resulting multiple regression equation:

Table 9: Summary of regression analysis.

```
Residuals:
     Min       1Q   Median       3Q      Max 
-12487.9  -2131.8   -177.2   1715.1  22310.9 

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)    
(Intercept)          5788.5     3610.1   1.603 0.109504    
facility_area1       -758.7     1972.3  -0.385 0.700651    
facility_area2        291.9     1881.9   0.155 0.876791    
facility_area3       1570.6     1929.5   0.814 0.416051    
facility_area4       2132.9     1957.1   1.090 0.276349    
facility_area5       2504.9     1975.5   1.268 0.205420    
facility_area6       4161.9     1972.5   2.110 0.035390 *  
facility_area7       6690.2     2087.3   3.205 0.001441 ** 
facility_area8       4527.8     2452.4   1.846 0.065480 .  
facility_area9      23432.6     3044.7   7.696 8.24e-14 ***
occupant              410.3      172.8   2.375 0.017964 *  
municipality1       -2190.9     4010.6  -0.546 0.585140    
municipality2        3551.0     3705.1   0.958 0.338357    
municipality3       -3247.2     3699.6  -0.878 0.380541    
municipality4        2879.7     4948.9   0.582 0.560918    
municipality5       -4798.2     5003.5  -0.959 0.338071    
municipality6       -1877.4     4986.4  -0.377 0.706710    
municipality7       -1372.9     4056.5  -0.338 0.735183    
municipality8         241.4     2866.8   0.084 0.932920    
municipality9       -5389.3     4981.6  -1.082 0.279882    
municipality10       5071.1     4927.8   1.029 0.303975    
municipality11      14623.2     4975.3   2.939 0.003452 ** 
municipality12      -4135.2     4982.0  -0.830 0.406940    
municipality13       -640.5     4116.4  -0.156 0.876418    
municipality14      -4101.6     3753.0  -1.093 0.274996    
municipality15        662.7     4972.4   0.133 0.894026    
municipality16        188.5     3063.8   0.062 0.950975    
municipality17       4080.3     4968.9   0.821 0.411964    
municipality18       6787.6     4989.4   1.360 0.174345    
municipality19        466.4     2993.9   0.156 0.876267    
municipality20       -203.0     5070.9  -0.040 0.968082    
municipality21       -674.5     4044.9  -0.167 0.867641    
municipality22       3121.8     4965.3   0.629 0.529836    
municipality23      -6412.6     5077.3  -1.263 0.207212    
municipality24       3137.8     3261.9   0.962 0.336568    
municipality25        655.3     4972.4   0.132 0.895202    
municipality26        765.9     4075.8   0.188 0.851026    
municipality27      -4948.3     5011.5  -0.987 0.323958    
municipality28       5416.3     4923.6   1.100 0.271867    
heating_type1       -4782.4     1277.7  -3.743 0.000204 ***
heating_type2        5762.7     1380.7   4.174 3.57e-05 ***
heating_type3        3373.9     1371.1   2.461 0.014225 *  
heating_type4        4610.2     1293.7   3.564 0.000403 ***
construction_year1    809.4      987.3   0.820 0.412730    
construction_year2   1356.5      767.4   1.768 0.077741 .  
construction_year3    989.3      790.4   1.252 0.211337    
construction_year4    985.8      835.3   1.180 0.238565    
construction_year5   1427.4     1074.3   1.329 0.184604    
construction_year6   -176.5     1234.2  -0.143 0.886343    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 3973 on 473 degrees of freedom
Multiple R-squared:  0.7249, Adjusted R-squared:  0.697 
F-statistic: 25.96 on 48 and 473 DF,  p-value: < 2.2e-16
```

4.3.1.1 Econometric analysis of results

The resulting multiple regression equation is deemed significant and can be used as a predictor for electricity consumption. The limit for an independent variable to be considered significant was decided to be a p-value less than 0.05. Facility surface area is in general deemed as a significant predictor of electricity consumption, the reason being the varying size of the surface interval, the bigger intervals seeming more significant in the multiple regression equation. If the intervals were of the same size or if the values had been exact, the facility surface variable is thought to have been significant and more accurate. Occupants and heating type are also significant independent predictor variables.

The multiple regression model indicates that the null hypothesis can be discarded for facility surface, number of occupants and heating type. The significance of these dependent variables, in turn, indicate that they can predict electricity consumption for the population. For facility surface area, an increasing surface predict a higher electricity consumption. A facility surface area of 300+ m^2 predicts an approximate 23400 kWh increase in electricity consumption over a year while a facility surface area of 250-299 m^2 predicts an approximate 4500 kWh increase, compared to the intercept. A graph was constructed, mapping electricity consumption over facility surface:

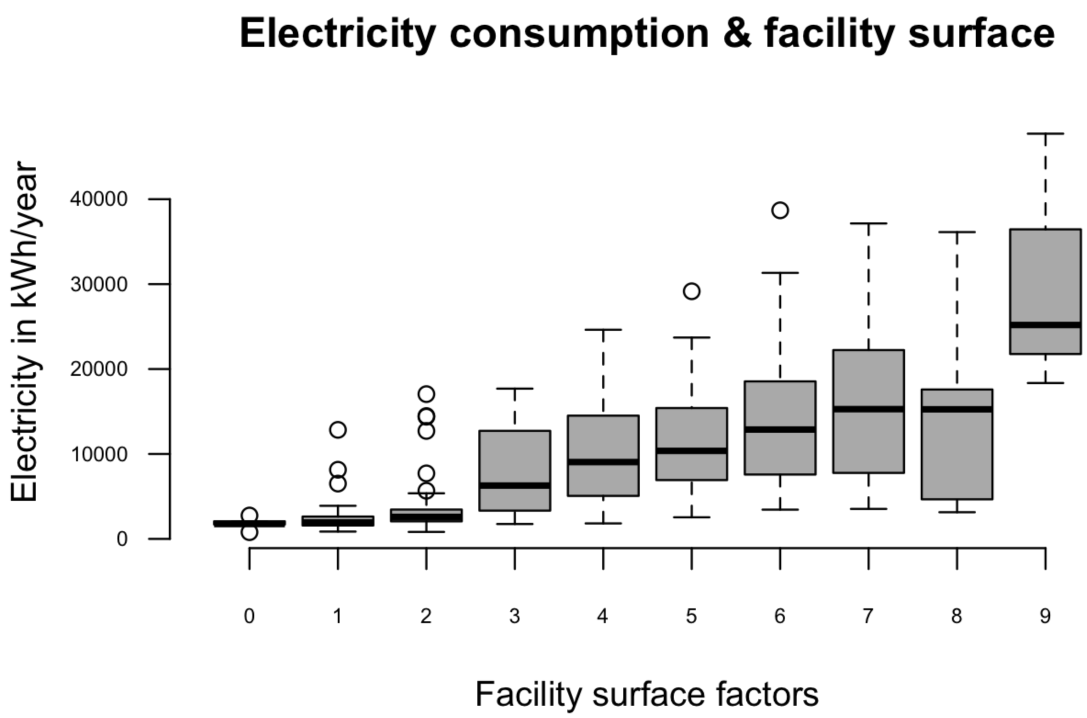

Figure 2: Electricity consumption per year for different facility surfaces

As can be seen in Fig. 2 the graph is trending upwards, with the exception for a facility surface area of 250-299 m^2. A facility surface area of 200-249 m^2 had one extremely high value far from the box, possibly heightening the mean value of the statistical material substantially and has, therefore, been removed. The facility area factors can be misleading. Respondents themselves input their housing surface but the surface consuming electricity can be even bigger e.g. having a garage or stables which will affect the results. For occupants, the following graph was constructed:

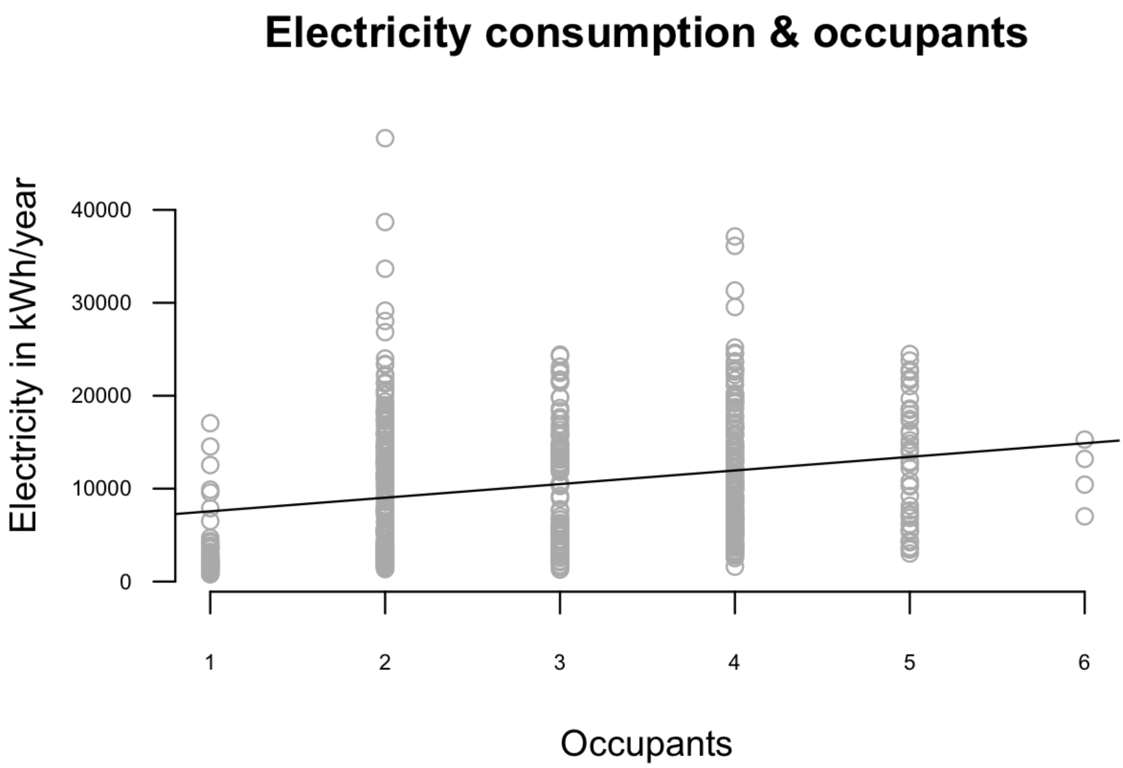

Figure 3: Electricity consumption per year for the number of occupants

As Fig. 3 shows, the graph is also trending upwards, meaning that an increasing number of occupants can predict a higher electricity consumption. More people in a residence means more people consuming electricity, this is thought to be due to an increased need for lighting in separate rooms, an increased use of utensils, computers, televisions, and more showers etc. The model predicts that for every additional occupant, electricity consumption increases by approximately 410 kWh. A graph was also constructed for heating types and the different heating types effect on electricity consumption i presented in Fig. 4.

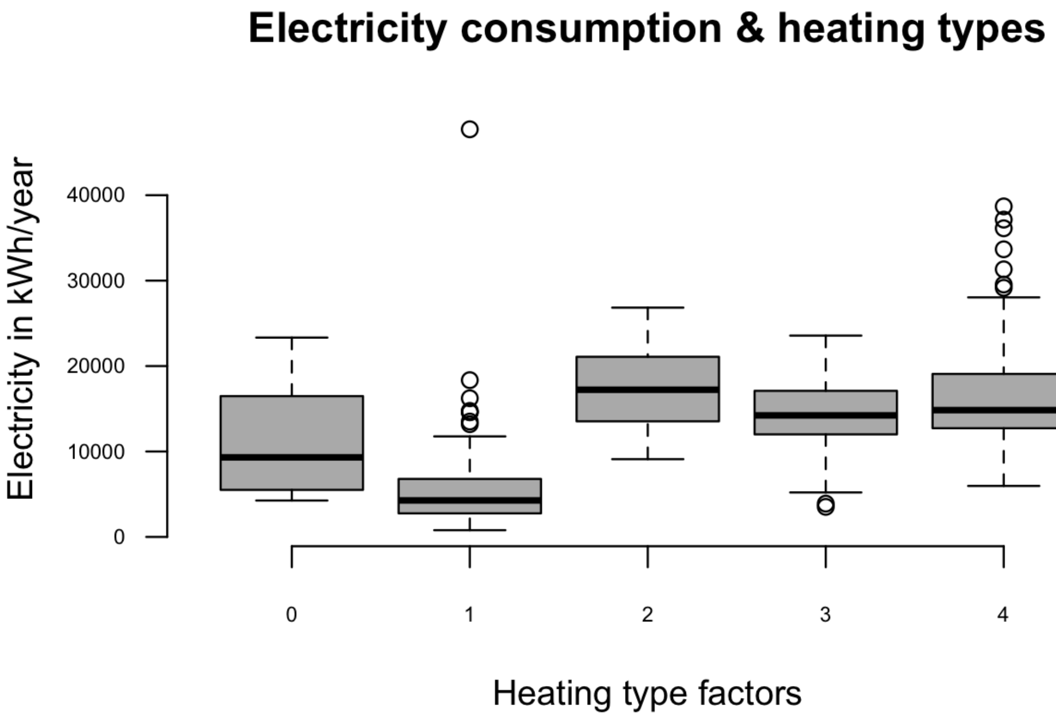

Figure 4: Electricity consumption per year for different heating types

For heating types, all factors were significant. As hypothesised, using direct electricity (Heating type 2), the model predicts an increased consumption, in this case equalling approximately 5800 kWh/year. For Heating type 1, district heating, the model predicts a decreased consumption of almost exactly 4800 kWh/year. This was a surprising result since using a boiler, intercept, seemed like the obvious least consumer of electricity. The reason for district heating being predicted to consume less electricity than the intercept is most likely due to the way the heat is produced. Water is heated centrally through combustion of waste and residual heat, then distributed, and does not produce or consume electricity. The model's prediction that district heating decrease electricity consumption is believed to be because of this reason.

In summary, more occupants increase consumption, a bigger surface area increase consumption and using direct electricity for heating increase electricity consumption the most among the heating types. Municipality and construction year are not significant predictors of electricity consumption. This is thought to be due to the low number of observations for many of the municipalities and other factors not varying too much between municipalities as well as continuous renovations to buildings making the construction year not matter as much. Even though district heating consumes energy to produce heat, it does not consume as much electricity according to the model. Using solar photovoltaics for district heating might be a viable option for levelling out the net load demand curve of electricity by heightening the electricity demand during midday hours and decreasing demand during peak consumption hours. To minimise consumption, in accordance with the model, residents should stay as many as possible in every residence which might be less a behaviour-oriented solution than cultural oriented and use district heating or a boiler. Using these heating types is counterproductive, though, since they rely on fossil fuels in the production of heat.

This approach to predict electricity consumption is similar to the approach proposed by Kavousian et al., (2013), using determinants instead of behaviour as predictors. Even if behaviour plays a big role in consumption, 72,49 percent of the variance in the dependent variable can be predicted with the independent variables, confirming the research of Kavousian et al., (2013) on using determinants instead of behaviour in predicting electricity consumption.

4.3.2 Water Consumption

Company X, where Expert 2 work, initiated a project to install individual metering and billing of water usage in apartments in two areas in Gothenburg. When asked why they initiated the project in the first place he stated:

"It was a pilot area and we wanted to see what effects individual metering and billing had on water consumption. We view it mostly as a topic of fairness." (Expert 2)

They launched the project in two different areas in Gothenburg in late year 2015. The project was later cancelled in year 2018 because of cost inefficiency and not attaining a desirable enough result. All residents were informed of the individual metering before-hand and was also informed of the new pricing models that would step in.

"The set amount was negotiated with the tenant union and was determined based on a 'normal consumption' per square meter. Then you either got money back, or payed extra, depending on your consumption." (Expert 2)

Billing was not linear with water consumption but was instead determined depending on if the resident had used more or less than a set amount which depended on the size of the apartment. The resident then payed a higher set price if consumption exceeded the benchmark and got a set price back if consumption fell short of the benchmark. The water consumption for year 2011 through 2018 in Area 1 is presented in Fig. 5 below. The data is, however, limited. It only provides the total consumption of the area and provides no information about the total number of people living there, or whether it is the same people living in the area during the time period. There is also no information regarding the demographics of the people living there, renovations that might have fixed potential water leaks, etc.

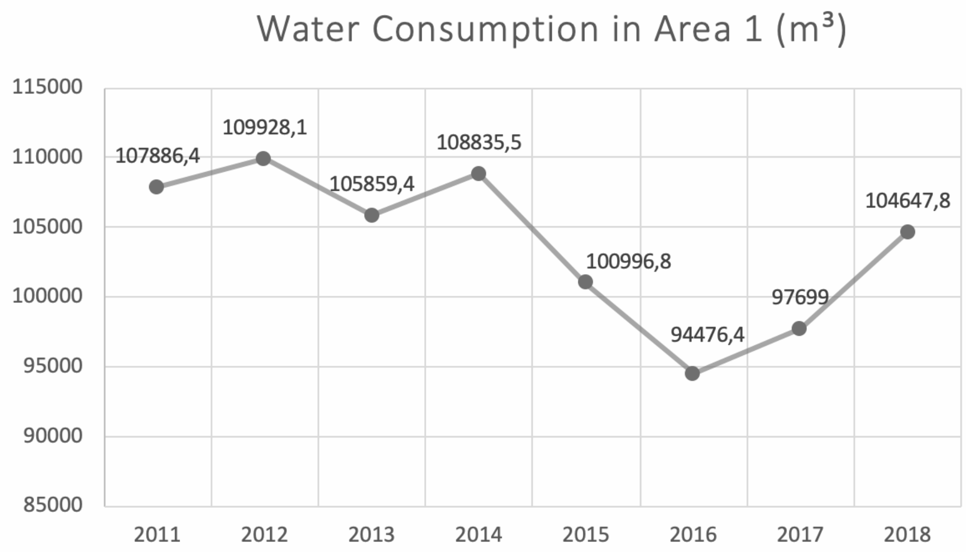

Figure 5: Water usage in Area 1 before and after implementing individual metering and billing in year 2015 (Source: Expert 2, 2019)

As can be seen in Fig. 5, individual metering and billing did in fact result in a reduction of water consumption for year 2015, 2016, 2017 and 2018. Though, in year 2017 water consumption started to increase compared to the consumption of year 2016. Expert 2 thinks the result can vary depending on where individual metering and billing is implemented:

"[...] and we would expect a much bigger difference in consumption for socially exposed areas after implementing individual metering and billing." (Expert 2)

The levels of water consumption in Area 1 has not yet reached the same levels as any of the years included in Fig. 5 before implementing individual metering and billing, but consumption seems to be increasing. Expert 2 explains how only implementing individual metering and billing in more socially exposed areas is unethical and gave no indication to whether Area 1 or Area 2 would be considered such an area. With "bigger difference", he means less water consumption, as the incentives to lower consumption below the benchmark, arguably, would be more attractive for those that need the money more. The results in Area 2 after implementing individual metering can be seen below in Fig. 6:

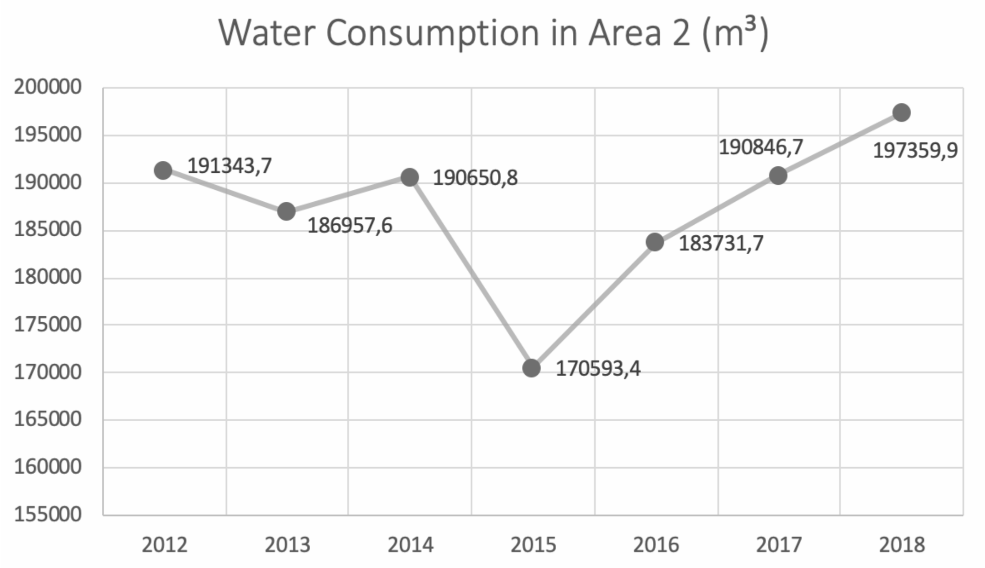

Figure 6: Water usage in Area 2 before and after implementing individual metering and billing in year 2015 (Source: Expert 2, 2019)

There was a reduction in water consumption for year 2015, which was the year individual metering and billing was implemented, and for the following year. In year 2017, the water consumption exceeded the consumption of year 2014 and further increased in year 2018. What separates the results for Area 1 and Area 2 is the decrease in water consumption for both year 2015 and 2016 for Area 1. Area 2 only maintained a decreasing consumption for year 2015, however, consumption for year 2016 did not exceed consumption for year 2014, it did in year 2017. Referencing back to the total increase in water consumption, Expert 2 said:

"We don't know how many people live in our apartments and residents have the right to live as many as they like in our apartments. We know, however, that there has been a densifying of residents, which can be seen in the total water consumption that has increased 10,5 percent in the last 6 years." (Expert 2)

The water consumption for Area 1 is both consistent, increasing total consumption, and inconsistent, decreased total consumption, with this statement. For Area 2, the findings seem to be consistent with the statement, especially in conjunction with the following graph of the total water consumption for all of Company's residences.

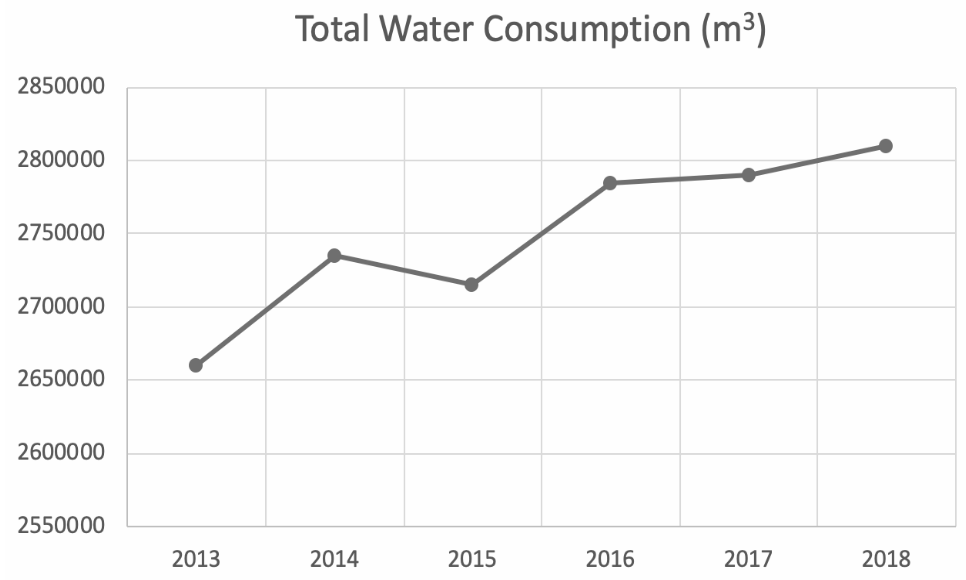

Figure 7: Total water consumption of Company X's residents (Reconstructed graph)

Water consumption seems to be increasing as Fig. 7 shows. However, the 10,5 percent increase might be a miscalculation from Company X, calculations using the numbers in the graph instead results in an increase of approximately 5,6 percent. Year 2015 is inconsistent in terms of increasing consumption. It is likely attributed to the introduction of individual meter and billing that year as the difference in consumption between year 2014 and year 2015 is roughly 20 000 m^3 of water which is similar to the consumption decrease for Area 1 and Area 2 for the same years, equalling roughly 30 000 m^3.

Between year 2014, one year before implementing the project, and year 2018, Area 1 has decreased its water consumption by 3,85 percent, while Area 2's consumption has increased by 3,5 percent. If the general densifying of residents is assumed to be symmetrical in all of Company X's areas and the implementation of individual metering and billing varies in effectiveness depending on sociographics, it can be seen that it is, in fact, effective in some cases, even in the long term. Area 1's residents seem to have kept the behavioural changes after the termination of the project, indicating that individual metering and billing can be a viable option for lowering water consumption. This decrease is evident when consumption feedback and billing is infrequent, i.e. monthly, and a bigger difference is expected if more frequent billing is present, assuming that billing frequency has the same effect on water consumption as it has on electricity consumption.

5. Conclusions

The objective of this thesis was to investigate how residential electricity- and water consumption can be reduced. Four areas regarding reducing electricity- and water consumption have been thoroughly analysed, namely the effects of pricing models, products and services, housing companies' role and residential behaviour. To answer the main research question: "How can consumer commitment in reduction of residential electricity- and water consumption be sustained?" four sub-questions were formulated, whose answers will help answer the main question.

Q1: What effect does price models have on electricity- and water consumption?
The price of electricity and water affect residents' consumption. It has previously been shown that not only price, but income as well, can influence the consumption behaviour of residents. If electricity is included in the rent of a rented home, the residents are likely to consume more electricity than a resident of a similar privately-owned home that pays a separate electricity bill. If, on the other hand, electricity is not included in the rent of a rented home, a similar privately-owned home is likely to consume more electricity. To reduce electricity consumption in general, electricity is not recommended to be an included utility in the rent bill. This is argued to have the same effect on water consumption, supported by the results of individual metering and billing of water, which indicate that behavioural consumption changes are kept in the long term.

Q2: What emergent technologies or services can lower electricity- and water consumption?
There are several products and services whose purpose is to reduce consumption of electricity and water. The solutions are to a higher extent related to electricity saving while water saving solutions are scarcer. The effectiveness of these products or services has not been considered, however, this shows that there is a market for consumption reduction and that connected gadgets can facilitate the metering of both electricity and water. The responsibility of acquiring and using these gadgets or individual metering and billing technology has not been allocated.

The consumption reducing effects of taking part in metering information through a service is evident for electricity consumption as well. The service Greenly, which visualise electricity consumption, has managed to reduce their users' electricity consumption by 6,3 percent, the effects were short lasting for some while others carried behavioural changes. The effect of price and income seem to not be the primary reason for changing residential consumption behaviour.

It rather seems to be the information and feedback the residents get on their consumption that have a higher likeliness of changing the residential consumption behaviour. The experts seem to believe that individual metering and billing does not work, or at least not to a good enough extent to be worth the investment. There is evidence that the effects are short term, as for Company X's Area 2 and for some of Greenely's users. There is, however, something missing in the solution that is individual metering and billing. In order to create a longer lasting commitment in reducing electricity- and water consumption, gamification has large potential.

Q3: What role does housing companies play in facilitating the reduction of electricity- and water consumption?

Today, housing providers do not want to interfere with their residents. Housing providers do make an effort in reducing electricity- and water consumption, and has succeeded well, but it is related to maintenance, renovations and heating optimisation etc. Their role in facilitating a reduction of residential electricity- and water consumption is passive. If they want to remain as passive, they should stop including electricity in the rent, converting their passive role in residential electricity consumption to a passive pressure from price of consumption for the residents. At the moment, housing providers are waiting for cheaper technology for metering water consumption and this waiting game has been ongoing for almost 20 years. One of the problems related to water metering has been the high costs, making it not an economically feasible investment.

Q4: How involved are residents in their electricity- and water consumption?

It was found that the residents had very little knowledge on how much they consumed of either electricity or water. Some of the residents knew how much their electricity bill costs but not the quantity of kWh consumed. None of the residents knew how much water they consumed, not monetary nor in m^3. All of the residents contributed in their own way to live more sustainably, some recycle to a high extent, some eat more vegetarian, some uses public transport, some shower for shorter periods of time and some turn off lamps. However, the general sustainability aspirations did not lie within lowering electricity- or water consumption. It was also found that residents do not feel like their actions matter which likely is a result from the lack of information of the effects of their behaviour.

5.1 Recommendations

Given the results, it is recommended that electricity and water should not be included utilities in the rent. Consequently, individual electricity and water meters should be installed in multi-apartment buildings which do not include this today. It is recommended that housing providers that, today, includes all utilities are responsible to provide metering opportunities and visualisation instruments for both electricity and water. For apartments that do not have utilities included in the rent, the responsibility should lie with the electricity- and water provider to offer metering and visualisation opportunities. To further engage residents and keep them engaged in the long term it is recommended that a gamified version of Greenely's service is developed. The service should optimise the presented consumption data, its frequency and quality to increase commitment by appealing to all types of users. Hopefully, the behavioural changes are sustained for a larger group of users.

Furthermore, to increase resident knowledge of residential consumption, housing providers are recommended to involve the residents more in their consumption by providing the consumption data in ways which the residents can understand and act upon. This includes comparison of the residents' consumption data with similar households so the resident can evaluate their performance and be provided information on how to lower consumption. Though, the responsibility of taking part of the metering information falls on the residents.

5.2 Limitations and further research

Since the factors of domestic water usage are complex, and not the same for all locations, the results of this research are limited to Gothenburg, Sweden. However, the behavioural implications are considered to be the same for the rest of Sweden. Furthermore, parallels have been made with electricity and water consumption because of the similarities in price models and consumption behaviour regarding these. The regression analysis had to exclude facility type because of the risk of collinearity, which was unfortunate due to it being an interesting factor. There might still be collinearity in the model, but it cannot be determined without testing. Since there are a lot of categorical variables in the model, this was considered too hard to perform. If there had been access to exact values for the variable surface area, the results are expected to have been more precise and able to predict the consumption increase for every additional m^2, given that the independent variable is still significant. The data provided by Greenly included the consumption of one year after signing up to the service. It would have been interesting to perform a multiple regression analysis with the consumption difference as the dependent variable, however, it was not.

Further research should focus on how to realise metering of both electricity and water and provide consumption data for all residents. Other research areas are how to gamify services such as Greenely and what effects can be realised, or how the housing companies can gamify the data from individual metering and billing technology to examine the residents' behaviour and changes in consumption. Moreover, as water metering has been considered an expensive installation with high administrative costs, this should be given further focus. Either on how to facilitate the administration of water consumption data, or how to make the water metering technology cheaper. It is also vital that research on how to incentivise housing companies in providing metering technology for the residents is considered. Besides behavioural science research, attention should be attributed the storing of electricity in order to level out the net load demand curve.

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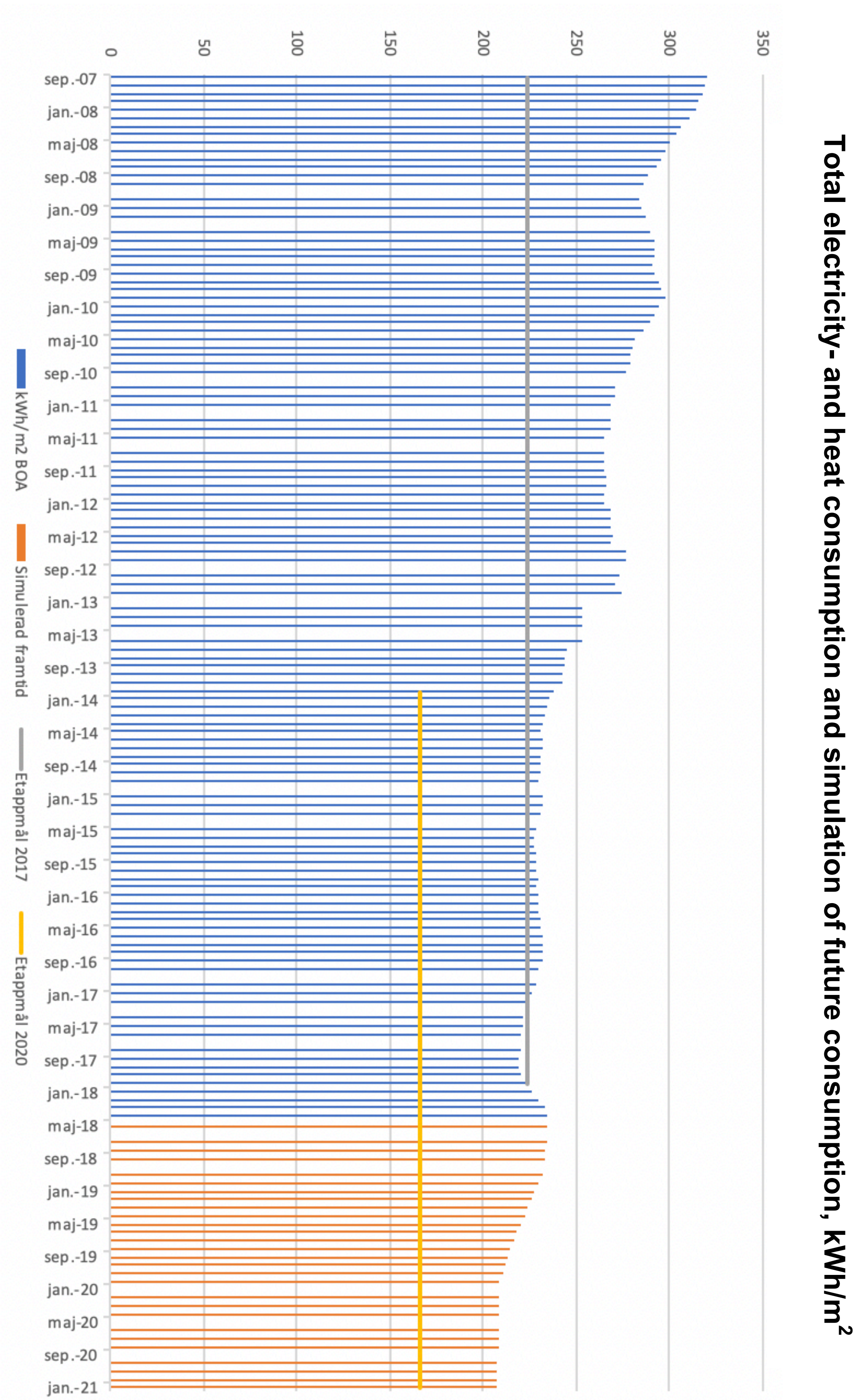
Annex I



Historical and simulated expected electricity and heat consumption in kWh/m^2 at CSB

Appendix I

Interviews were held with seven residents with the aim to understand residents' behaviour and habits in sustainable living, and to understand their level of knowledge of their consumption. The questions asked to the residents are presented in bold text, the answers from residents are presented in italic. Below are some demographics of the residents presented.

Resident	Gender	Age	Occupation	Educational Status
1	Female	24	Student	University Student
2	Male	29	Working	University Degree
3	Male	25	Working	Upper Secondary School
4	Female	22	Working	Upper Secondary School
5	Male	63	Working	University Degree
6	Male	24	Student	University Student
7	Male	25	Working	Upper Secondary School

When asked about what the residents do in their home to live more sustainable the residents answered:

"I try to buy organic and locally produced food and I have also started to eat less meat […] We recycle everything [...], but we know that we need to be better at recycling papers. We always try to think of not having unnecessary electricity consumption, we turn off lights we don't need, the radiator is only used when it's really cold. We bought a radiator because it's often cold in our apartment as the windows leak. That month I had it on quite a lot and the month after the electricity bill was 600 [SEK], usually it was about 200 to 250. After that I only turn it on in the morning as it gets cold during the night." (Resident 1)

Resident 1 mentions buying organic and locally produced food, eating less meat, recycle and thinking of the electricity consumption as her way of living more sustainable. To lower water consumption is not considered by resident 1 when answering this question.

"I don't buy meat, not because of the environment even though I know it's better, I just don't like it. I don't buy pig or cow […] I cook more vegetarian food but I'm not an active vegetarian. […] I don't buy ecological food, mostly because of the price, I rather buy locally produced." (Resident 2)

When answering the question about what Resident 2 answers that he eats more vegetarian and buys locally produced food. There is no mentioning of lowering energy- or water consumption by Resident 2.

"I think of turning off lights I don't use. […] I turn off the shower while soaping myself. I recycle, but I would like to have bigger areas in my kitchen to easier sort my trash. […] I gladly buy locally produced food, but my budget is constrained. [...] I actively try to inspire people to take care of the planet, since it's so beautiful, and I try to spread veganism. [...] maybe I have an impact on people's thinking." (Resident 3)

Resident 3 mentions that he thinks of both electricity- and water consumption to be more sustainable. Moreover, he recycles and eats vegan and actively talks and tries to inspire others to live more sustainably.

"I use the public transport a lot, I recycle trash, clothes and similar. I think of buying locally produced food. Reuses fabric bags instead of buying a new plastic bag all the time. I also think of not wasting hot water but only use what's necessary during hand wash of the dishes, shower and so on. I only wash clothes when I can fill up a machine and I turn off lamps after I leave a room, and seldom have lamps on in daylight." (Resident 4)

Resident 4 seems to live more sustainable than most of the other asked residents. She mentions using public transport, buying locally produced food, recycles and reuses things, as well as, thinking of both her electricity- and water consumption.

"I try to stick to some sort of energy conservation and even though I'm a habitual meat eater we have succeeded with changing habits to more sustainable. I have during many years consistently bought organic and fair trade marked food, but I realise now that it's luxury consumption, and maybe not as environmentally friendly as I've thought. [...] anyway, I feel more insecure today of what is good for the environment than a couple of years ago." (Resident 5)

Resident 5 mentions that he tries to stick so some sort of energy conservation, although he does not mention what he does to lower energy consumption. He also says that he eats more vegetarian as a way of living more sustainable. He mentions that he buys organic and Fairtrade food but lately there seems to be bigger insecurities of what products to buy that are better for the environment.

"I'm vegan, which is good for the environment, but that's not why I'm vegan, it's mostly because it's healthier. I turn off the lamps when I leave my apartment and I mostly travel by public transport [...] I would probably not use the car even if I had one. [...] The people in my shared kitchen isn't very good at recycling so I gave that up almost immediately when I moved here. [...] Sometimes I shower for a long time, but I try to keep it short. [...] I don't know how much electricity is consumed when I use my mixer table and my speakers at the same time, but I think they consume a lot of electricity so I minimise how much I use it so there is no power failure." (Resident 6)

The main argument of resident 6 is that he eats vegan but not for sustainability reasons. He tries to minimise unnecessary consumption by turning off the lamps and taking shorter showers. A recurring element is that his actions that he considers sustainable is not because he wants to consume less but because of other reasons, e.g. using public transport when not having a car.

"To live more sustainable at home, I recycle as much as possible, I try to turn of the shower when I'm not directly using it and turn of lights and such when I leave home." (Resident 7)

Resident 7 mentions recycling, thinking of water consumption while showering and turning off light as his primary ways of living more sustainable.

When asked about what the residents wants to do more to live sustainable the residents answered:

"I am a person who really likes to shower, I shower for a very long time, but I think of lowering the water pressure [...] but I shower around ten to fifteen minutes. Actually, I have changed my behaviour because I don't take baths even though I like bathing. I try to lower the temperature on the water even though I like when it burns, but it's also because it's bad for the hair. [...] you have some bad stuffs you do, one thing is that I feel like it is a luxury to have water and then I feel that I enjoy it and consciously stay in the shower because I have the possibility. [...] actually you can just take shorter showers, I could change, but then I feel like a small part of my comfort decreases." (Resident 1)

When answering this question resident 1 seems to have given some thought of her water consumption and have changed behaviour to some extent. Although, she does not want to take shorter showers because of the perceived luxury of standing in the shower for a long time.

"*I would like to drive an electric vehicle, although it's not up to me to decide, but the company I work for, it's a too big cost for me to buy one myself. [...] I want to opt out of the Spanish vegetables because of the poor working conditions. [...] I'm not very careful of my things and I often buy new things and not on second hand." (Resident 2)*

Resident 2 wants to live more sustainable by driving an electric vehicle, but the costs are too high for him to buy his own car as the company he works for provides him with a car. Moreover, he mentions that he wants to buy other vegetables than the ones from Spain, not because of the sustainability aspect of eating vegetables, but for the perceived bad working conditions. Lastly, he seems to know that it's more sustainable to buy products on second hand but there is not any indication on that he will start doing to.

"I want to be better at recycling, and not wash the dishes under running water in the sink. I want to inspire more people to not litter and live sustainable, [...] and make people not feel like single drops in the ocean." (Resident 3)

Resident 3 seems to know that it is not good to wash the dishes in running water but does it anyway. However, for Resident 3 it seems like he thinks of inspiring others to live more sustainable as the principal way of making the world more sustainable overall.

"I want to be even better at buying locally produced and organic food, but it's more expensive and I don't have the economy to do it as much as I want." (Resident 4)

For Resident 4 the reason for not following her own advice of buying locally and organically produced food is the perceived higher price of those products. It seems like economy is what constrains her the most in her way of living more sustainable.

"I think of myself as a "moonlight farmer", I enjoy self-catering and growing and so on. I have a summer house for this. [...] I think it's absurd that we make a bowl in white porcelain and then we take our pants of and do what we do and flush it away with freshwater. [...] I'm trying an electric toilet at my summer house, which turns the excrement to ash which you can use as fertilizer. [...] to lower energy consumption I believe is a very important factor. Also, to lower the overall household consumption and of course the car, to drive less. [...] at summer to think of the air conditioner." (Resident 5)

Resident 5 thinks of producing his own food as a way to be sustainable, although he seems to have an interest in gardening which might be the primary reason for growing his own food. He seems to have given some thought of the toilets we use and that we use freshwater to flush and that it might not be the most sustainable. He has an electric toilet at his summer house, although the electricity consumption to burn the excrement is something to take into consideration if it is a better alternative. Moreover, he believes that to be more sustainable the energy consumption is one of the most important factors together with driving less car. Though, he did not mention that he actually thinks of lowering his own energy consumption and/or driving less car.

"Recycling, I wish the people in my kitchen recycled better because I was very good at that before I moved in where I live now. [...] I want to buy less products with plastic wrappings, but everything is wrapped in plastic right now, someone should develop a better alternative. [...] I need to be better at plugging out things from the sockets, all my music producing gear consumes a lot of electricity when it is in stand-by mode. [...] also, closing the windows and lowering the radiator instead." (Resident 6)

Resident 6 wants to buy less plastic-wrapped foods but admits that it's hard when everything nowadays seems to be wrapped this way. He also mentions the collective responsibility for recycling in a shared kitchen and wants the other people in his kitchen to be better so he can as well. In conjunction with the notion of buying less plastic-wrapped foods, it seems like resident 6 wants to live more sustainably but cannot without the help of others. He also wants to be better at regulating the temperature in his apartment in a more electricity efficient way.

"What I can do better is to take out chargers out of sockets when I leave home and not use all the electronics at the same time. Why I don't do it is fully based on laziness." (Resident 7)

To live more sustainable, it solely means for resident 7 to change habits regarding activities that can lower his electricity consumption. Although, the obstacle for why he does not do it at the moment is laziness. Therefore, these habits need to be replaced with the habits of doing what he knows he should do. This is most likely to happen if he can feel pleasure or like an achievement to take out chargers of sockets or turning of electronics.

When asked about the knowledge of energy and water consumption the residents answered:

"The only thing I know is electricity, but I don't know what we consume only what we pay so you can see if you have consumed more or less. [...] water consumption I don't know." (Resident 1)

Resident 1 does not know how much energy she consumes only what she pays for it. Money seems to be her way of measuring if she consumes more or less electricity. She does not know how much water she consumes.

"I have no idea. I pay after a standard for my electricity consumption which they measure individually [...] it's the housing cooperative that stands on the electricity agreement. [...] I can see my electricity consumption on the invoice, but I don't know how much I consume, only what it costs. [...] I don't know water consumption." (Resident 2)

Resident 2 does not know how much electricity he consumes even though he has individual meteringof electricity. He also seems to measure his consumption on how much it costs him monthly. He does not know his water consumption.

"I don't know, I can check the electricity bill, but I don't know what electricity provider we have. I think that people should have better knowledge of their energy consumption, including myself, but how engaged do you have to be? I have to have time for my life too." (Resident 3)

Resident 3 does not know how much electricity or water he consumes, and he does not know which electricity provider they have either. Even though he does not know his energy consumption he believes that people should have better knowledge of their energy consumption. There seems to be some struggle with how engaged you need to be in your energy consumption. He mentions that he has to have time for his life which might be that he thinks that it takes a lot of effort or time to know the energy consumption and change it.

"I don't know either electricity- or water consumption. It's included in my rent." (Resident 4)

Resident does not know her electricity- and water consumption. Despite that she cannot access and know her consumption she still thinks of lowering it.

"I know it, but I have a very bad memory for numbers, I have four electricity invoices at two different addresses, so I have no idea. [...] I don't know the water, in one case it's the landlord which provides the water, and in the other case it's a water pump which needs to be warmed up to the dishes and showers. It's a limiting factor, a water heater only lasts a short

moment and then the water feels as cold as ice, which makes you not so tempted to take long showers." (Resident 5)

Resident 5 first says he knows his electricity consumption but that the number of invoices he gets for his two housing makes it hard to know. It might be so that he mixes them up or it might be that he does not know actually how much electricity he consumes. He does not know his water consumption, but in the house where they have a water pump, he seems to think more of how much water he consumes.

"No, I don't know. Electricity and water are included in my rent and I don't even know if I can find out. I probably consume more electricity than the others living here but since I live in such a small apartment it can't be that much more. [...] In some apartments I think people live in pairs and they shower more than me, but I don't know how much I consume of either water or electricity." (Resident 6)

Resident 6 does not know how much water or electricity he consumes since it's included in his rent but not on his bill. He seems to know of his consumption in relation with others living in same sized apartments in his apartment building and knows that some of the things he does consumes a lot of electricity but does nothing about it. Resident 6 seems like a passive fighter for sustainability since he does not actively take many initiatives in living sustainably but aspires to do so.

"I do not know my consumption. I've heard there is an app you can use to track it. [...] It's the same with water, I do not know it either. I can see my electricity costs when I pay the invoice, but not water consumption. Actually, I have no idea what things costs, like having the shower on for X minutes or turning of the TV, how it changes. The environmental effects I have even less knowledge about" (Resident 7)

Resident 7 does not differ from the other residents' answers on the question. He does not know either electricity- or water consumption. Though, he is familiar with the application Greenely, but he does not use it himself. Furthermore, he mentions that he does not know the effects of his behaviour on the environment or monetary.

Appendix II

Three expert interviews were held and the quotes and interpretations from the interviews are presented in this Appendix.

Interview with Expert 1 about Gamification

Expert 1 is currently working at CGI as an innovation manager. He has worked as a project manager in several projects including gamification. The projects have been in different contexts, of experimental character but also in the development of new services that are used today. The interviewed focused on a project which the Expert worked on where the aim was to lower electricity consumption in a whole city.

When asked about what gamification is and how it works Expert 1 answered:

"Competition is only one thing in gamification. First we estimate what type of people there are in the group according to Bart's gaming types. One part are Achievers who like to compete and be in the leading positions. Socializers are the ones who often posts things, on Facebook for instance. Explorers are the ones who wants to explore and Killers the ones who wants to show that they can break the rules in smart ways" (Expert 1)

Expert 1 seems to use Bart's gaming types Achievers, Socializers, Explorers and Killers to categorise people's aims and behaviour when playing.

"Of you take it from a group perspective all these people should be in the development of the game so that all can come to the top. What many do wrong is that they create a competition where only one can reach the top and then companies believe that they have gamified the service or product, but it doesn't work. You have to think to get everyone aboard not just some. If you want people to stay in the service and to use the service, it's incredibly important to understand your users." (Expert 1)

For gamification to be successful these gaming types should be in the development of the game according to Expert 1. It seems like some companies who think they introduce gamified systems only design it for achievers and not the other types, which reduces the impact a gamified system can have when not all people's interests are included. To understand your customers seems like the key in designing gamified systems.

"[...] it's called the 'test gamification framework' which have seven different areas to include when you design games. It about understanding your organisational goals, understand your players and to create cycles that makes you not fall out. It important to understand the seven steps and to follow them. It's not easy but if you follow them it gets really good." (Expert 1)

Expert 1 seems to rely on this 'test gamification framework' when he develops gamified systems. Even though he does not describe the framework in detail it seems to be to find a solution that aligns the goals of the organisation with the goals of the potential users of the service.

When asked about why gamification is important, Expert 1 answered:

"Gamification is everything in the evolution, that a bear catches fish is gamification. Actually, gamification is the most natural there is and that's why I think that the word will disappear. Look at the way you build organisations, you get rewards and should develop the co-workers. It's both good and bad, we are here because we have survived. [...] Gamification is natural and nothing strange. You don't need to be a competitor to make it work. The gaming industry understands well how it is." (Expert 1)

Expert 1 makes a parable that gamification is how we live our lives and that it's nothing strange about it. It seems like Expert 1 believes the word gamification will disappear as people understand what it is about.

"[...] You should be aware of what you want to achieve, an important part is to control behaviour and steer towards these. That is the mindset you should have but you need to be good at breaking it down. [...] in gamification you get smaller challenges which all the time make you better. It's the behaviours you steer not the result. I think that you can notice it on organizations that you should steer behaviours, although, everyone is not there yet." (Expert 1)

Expert 1 stresses the importance of knowing what the goals are of the gamified system are. As gamified systems can be developed to control and steer behaviours you need to understand what motivates the change in behaviour. It seems like Expert 1 thinks that you should develop gamified systems to steer behaviour not to reach a certain result.

When asked about what sorts of gamification projects Expert 1 has worked with Expert 1 answered:

“It started with that I was to affect the energy consumption in a whole city in the most cost-efficient way as possible. I thought of what engages me, and realised that the world championship in football engages me the most and tried to figure how I could use it in the solution. [...] I was to make lots of people to love energy, and we tried all sorts of ways of how to get people to think different and change their energy consumption, without installing a single thing. The only thing we did was to communicate. We solely built it on communication with people and understanding their behaviour. People know what they should do, but you need to give them the mechanism to find their interest in doing so. People know that they should turn off the lamp when they leave a room, but by awakening the engagement you can actually make it fun to turn off the lamp.”(Expert 1)

To create a gamified system is seems like you can start from what engages yourself and others and try to convert this to gamification. Furthermore, it seems like it is not always necessary to include installations of devices, but the right communication can favour the change in behaviour that you seek to change.

“We lowered the electricity consumption by 2.5 percent throughout the whole of Växjö city. We measured everything and during several years. At that time there wasn’t even gamification as a concept. We had some researchers from Interactive Institute, current RISE, and used ‘Persuasive gaming’ to influence people and their way of being. [...] I was hired by the municipality and it was an EU-project which we conducted together with property companies, energy companies and the municipality.” (Expert 1)

During the project in Växjö they managed to lower the total energy consumption with 2,5 percent. As gamification did not exist as a concept yet it seems like they were at the front of using game mechanisms to change the everyday living behaviour and succeeded with it.

"We started to realise that we could affect people's behaviour. Humans are not just interested in energy saving tips, that's not how it works. We built visualization things and similar so that the people could see their energy consumption. Only by providing this people started to engage. Before you couldn't see your result and then you are not interested in changing something, games make it very clear." (Expert 1)

It seems like it is not enough to change behaviour by only giving energy saving tips, but that people need to see and understand their energy consumption. If you cannot see what you achieve it seems like you are not interested in changing.

"One has to create solutions that are interesting to use. But it's a giant threshold to get people to use it. We created many competition moments, a lot of PR and TV and we did something that nobody else had done before. [...] If we were to make a contest where the price was one monthly rent and we would get incredible behaviour changes. My CEO lived without electricity for a week when we tried similar but for companies. It got us to experiment with the usage of the solution. We got some extreme behaviours and even if it's not sustainable in the long-term you realise that you can do better than you think." (Expert 1)

It seems like solutions need not only to visualise the results, but they also need to be interesting and engaging to use. The experiments they made with different prizes shows that with monetary prizes people are willing to change behaviour to a great extent.

When asked about the penetration levels and involvement of the users of the solution in Växjö, Expert 1 answered:

"We could see a clear difference, some people just don't care and are unreachable. But we did reach out to some that we really had an impact on. We had about 40 000 measuring points, so it was hard to know exactly what was what. But at the same time, you can always buy your way to reach out to people but to engage people is not that easy." (Expert 1)

It seems like the challenge with creating a solution with the goal to lower energy consumption is not to reach out to all people but to engage them. Those who were engaged in the project seems to have changed behaviour but exactly by what was hard to know as the measurement points were so many.

"Basically, we had a model which we compared with different criteria, those with heating pumps and those without for instance. [...] we always compared with values which you could relate to and showed the percental savings. A lot was about showing the changes and comparisons with the same periods. We also compared zip codes, the neighbourhood and the same type of family constellations. The most important was to be consistent and to let the user know that it was compared with the same type of criteria of the other users. [...] It wasn't really about rewarding the winner but to increase the knowledge about energy consumption and to get people experimenting. We noticed that people started to talk about it with other people about it, and that's what we wanted to achieve." (Expert 1)

When the comparisons are done to see how well you perform in a gamified system, it seems to be important to use consistent and transparent criteria.

Interview with Expert 2 working at Company X

Expert 2 works as the energy director of a big housing company that is owned by the municipality of Gothenburg. His previous experiences include being the vice president and technology manager of a service provider for housing companies for ten years. Some of his responsibilities at Company X include aspiring to meet the public energy goals, making strategic decisions regarding energy and attending energy council meetings with Boverket, a Swedish property authority. He considers the housing industry as conservative and states that change take time but is vital.

When asked what data Company X gathers, Expert 2 replied:

"We've taken a big index-decision. We will install temperature meters in every apartment [...]. For new properties there is a new law that demands water meters if it is economically feasible. We have pilot projects in new areas, two pilots terminated. Area 1 and Area 2 was terminated. We saw that those two projects didn't live up to the investments, even if I see them as a just cause and not an energy initiative. We don't know how many people live in our apartments and residents have the right to live as many as they like in our apartments. We

know, however, that there has been a densifying of residents, which can be seen in the total water consumption that has increased 10,5 percent in the last 6 years." (Expert 2)

Company X started a pilot project to test the effects of individual metering and billing on water consumption. Company X, therefore, started gathering individual consumption data of water in two areas, here denoted Area 1 and Area 2. This project was later terminated due to it not being economically feasible even if the project was considered to be a just cause by Expert 2. Company X also measures the total water consumption for all their residents. As people are allowed to live as many as they like in the apartments, consumption per resident is hard to determine. The total consumption is increasing, which Company X want to counteract.

When asked how Company X plan to use the gathered data, Expert 2 answered:

"[...] work with day-to-day optimisation and analysis of heating systems and heat problems." (Expert 2)

Company X plan to install a few more kinds of meters that will help with optimising the day-to-day operations, the heating systems and help resolve some of their heating problems.

When asked why the individual metering and billing project was terminated, Expert 2 said:

"The operating costs are too expensive to find profitability in those systems. I do, however, expect development to be quick. We're testing providers of infrared technology to put on water pipes so you don't have to cut them to install meters. When the technology is cheaper, we can look into these options again. We will focus on the properties and things that do not affect the residents directly. When we implemented individual metering and billing, we changed the billing model so residents paid an amount if they consumed too much. The set amount was negotiated with the tenant union and was determined based on a 'normal consumption' per square meter. Then you either got money back, or payed extra, depending on your consumption. At first, we saw the water consumption decline but it quickly regenerated, I guess that is another reason for not keeping the project." (Expert 2)

The high operating costs seem to be the biggest driver to terminating the individual metering and billing project. Company X is waiting for a cheaper and more efficient technology to adopt the individual measuring technology. With the new billing model, Company X could initially see a decline in water consumption in Area 1 and Area 2, however, the consumption started increasing to levels higher than before implementing the pilot projects.

When asked if the focus lies on minimising consumption or making money, Expert 2 answered:

"We serve the common good. We are owned by the municipality of Gothenburg and all profits are reinvested in properties. Our biggest purpose is to serve the common good. We invest a lot primarily in the common good. Individual metering and billing is first most a just cause and we would expect a much bigger difference in consumption for socially exposed areas after implementing individual metering and billing. [...] The operating costs for the individual metering and billing system are very high. We get a lot of questions from the residents regarding their water consumption that we have to answer. The costs of maintaining the system are high and we see no "energy profit". All together there is no economic feasibility. It was a pilot area and we wanted to see what effects individual metering and billing had on water consumption. We view it mostly as a topic of fairness." (Expert 2)

Even if the reason for terminating the pilot projects seems to be the economic aspects, it can be traced back to the well-being of Company X's residents as all profits are reinvested in the properties. Expert 2 stresses the importance of their role as a servant to the common good and the municipality and the reasons for initiating the projects being a topic of fairness for the residents. Terminating the projects, when the costs of maintaining the system are so high and the individual metering and billing initiatives provide no long-term decrease of water consumption, seems like a reasonable response.

When asked whether or not Company X has tried any initiatives in order to lower their residents' water- or energy consumption Expert 2 answered:

"We will focus on water and swap all taps, in the kitchen, washing sinks and showers etc. to minimise water usage in these areas. Small initiative, but it works very well. Before, too much air has been mixed in the water which wasn't very much appreciated. Now, the water

pressure is changed independently of the water optimisation for the residents' better comfort, regardless of on what floor you live. We swap a lot of fans, circulation pumps and have lighting projects, a lot of continuous operations that lower the energy consumption. FTX-recycling in the ventilation, in these projects we also swap windows and facade which saves a lot of energy. We have seen almost a halving of energy consumption after a facade, window and ventilation swap. The main goal wasn't to lower consumption, but it was part of our continuous renovations. According to law, continuous checks of ventilation are mandatory."(Expert 2)

Company X's initiatives to reduce consumption is not regarding changing the behaviour of the residents but rather to make upgrades or using gadgets that lower consumption. This will not require any effort from the residents but will make some water- or electricity consuming product consume less. Some of the initiatives made include attachable, water pressure optimisation, and ventilation- and facade renovations etc.

When asked if Company X is doing any other sustainability initiatives, Expert 2 said:

"There was an official company group decision to install solar panels and we have gotten money from the municipality for it, and we installed our first solar panel project in an area last fall. This will help reduce the ratio between electricity that we buy and produce ourselves. Already, we manage to use 60 percent of produced electricity and 40 percent is distributed to the electricity grid." (Expert 2)

Solar panel is not an initiative to reduce electricity consumption but works as a driver for using more renewable energy. Even if Company X's residents cannot utilise all the produced electricity, the remainder is distributed to the grid. This provides some extra revenue but most importantly increase the use of renewable electricity for others as well.

Interview with Expert 3 working at Chalmers Studentbostäder (SCB)

When asked about individual metering and billing in apartments by CSB, Expert 3 answered:

"It doesn't work with individual metering and to pay for what you consume, it has been tested so many times, but it doesn't work. [...] I have tested it several times professionally but it's only one time it worked, that was when electricity first was included in the rent and then individual metering and billing was installed, but the electricity consumption was only lowered to normal consumption levels." (Expert 3)

Expert 3 seems to be convinced that installing individual metering and billing does not work after testing it several times. The only time it worked the electricity consumption levels was only reduced to normal levels.

"[...] from an economic perspective it's completely unnecessary to install electricity metering because there are too high costs. The costs of installing electricity metering corresponds to seven years of electricity consumption per household and then you have a life-span of maximum 15 years of the device. During those years you also have maintenance costs and handling cost and a lot of overheads." (Expert 3)

Expert 3 says that from an economic perspective, here interpreted as profits, there are no incentives of why you should install electricity metering. He says that there are too high costs related to maintenance and handling of the metering system. It is not further analyses whether his calculations of the cost of installing metering corresponds to seven years of electricity consumption per household are true. Although, it is understood that there seems to be high maintenance and handling costs with electricity metering.

"[...] you realise that it doesn't cost much to have a higher consumption. I calculated the money savings if a single student can achieve a 15 percent saving in water consumption. It's only one beer in a bar because water is so cheap. You need another sort of billing and to introduce some penalty for over-consumption. But there will probably be conflicts of where the limits are." (Expert 3)

Expert 3 seems to think that the cost of using water should be reconsidered and that it should be penalties for a higher water consumption than normal. As it is now, he seems to believe that there are no economic incentives to lower your water consumption when you barely save any money on it. Although, he does not mention where limits of over consumption should be and how the pricing model should change.

When asked about what type of data CSB gathers of their residents and how they use it, Expert 3 answered:

"*One of the data that is very important for us is the temperature data in the apartment, which we use to cope with the heat consumption in particular. In the apartments we already have individual metering and billing we gather data of electricity- and water consumption. Besides that, the electricity and water consumption are measured at the building level but not apartment level. We have one billing meter in every building which you cannot access as an individual." (Expert 3)*

Expert 3 thinks that temperature is one of the most important data they gather, which they primary use to cope with heat consumption. Further, he mentions that they gather data of electricity- and water consumption in apartments which already have had individual metering and billing installed. They measure the aggregated electricity- water consumption at a building level but not individually.

"After all, we have tried to charge after what the residents use. Available in the contract agreement it could say 'there is an electricity fee of 150 SEK'. If we have a functioning individual metering and billing system already installed, we count off monthly from a template. [...] We will not maintain the individual metering and billing systems or take out the data measurements from them any longer. It has been huge administrative costs related to this. Firstly, it's the administrative system we use to get the measurement data to us, then it must work technically with the rental system and then there are mistakes which costs a lot of money in working time. [...] some received far too much billing, and for some it could take up to half a year until they reacted. All the working hours spent destroyed all possible savings. [...] there are reasons why we have electricity companies that are familiar with electricity management and maintenance." (Expert 3)

At CSB the residents pay a fixed fee for the electricity each month despite how much they use. Even though if they have functioning individual metering and billing systems, they will not take out the data from them any longer because of the mentioned administrative costs. It also seems like the individual metering and billing systems are troublesome and that the data are not always correct as some residents had too high billing than what they had consumed. Expert 3 seems to believe that electricity companies should be the ones handling electricity metering instead of housing companies, as they are familiar with electricity management and maintenance.

When asked about the electricity contracts Expert 3 answered:

"CSB stands on the electricity contracts and it would not be an advantage for students to note their own electricity agreement. It would be problematic as students live quick lives with many changes and it might be that they cannot economically stand on electricity contracts. [...] we use Energy Sweden and shop at a portfolio of six GWh. We will include the electricity in the rent, and it will be a part of the lease, if electricity prices changes it will be negotiated too." (Expert 3)

At CSB it is not possible to have your own electricity contract. Expert 3 seems convinced that it is better that CSB stands on the contract because of the students' life situations. Furthermore, as the price of electricity which they buy might change then they might change the rents for the residents living in the apartments too.

When asked of what initiatives to reduce your residents' electricity- and water consumption CSB have done Expert 3 answered:

"The big investment was the individual metering that began in 2006, and then we have pushed the work forward to broaden it, but it was more wasteful to continue with it than to wind up." (Expert 3)

Expert 3 mention that installing individual metering and billing was the biggest initiative to reduce the residents' electricity- and water consumption. Although, he thinks that installing individual metering and billing was wasteful to continue with which made them wind it up. He does not mention other initiatives they made to reduce water consumption.

When asked about solutions on how to reduce household consumption, Expert 3 answered:

"It is desired that there is a coherent trend that draws on reducing consumption so that one can contribute to it. The biggest thing we have done for reducing consumption is without the participation of the residents, for example smart heat, not overproduction of heat but not that it should be too cold either. Internally, we say that we measure temperature, but if it says 21 degrees, it is not certain that it is right for the climate in the apartment. It might be shallow insulation or too much ventilation. [...] the biggest culprit is that we ventilate away the heat." (Expert 3)

What Expert 3 and CSB have done to reduce household consumption is mostly at a level that residents do not notice as it is without the participation of the residents. Given his answer it seems like ventilation is one of the biggest energy consumer, as the heat is ventilated away. It seems like they have noticed that the climate in apartments affects the energy consumption.

"We use carbon filter fans instead of only use ventilation over the stove. [...] carbon filter fans reduce the air circulation in the apartment, where the kitchen has one circulation and the bathroom another. [...] we have dramatically over-ventilated apartments which contributes to a really unnecessarily energy consumption. [...] as we filter the air instead of only ventilating it away, we have reduced the circulation with about a third, which we also have noticed on the energy consumption." (Expert 3)

Expert 2 seems to have found a way of reducing the amount of heat that is ventilated away by installing carbon filters over the stove. By doing this they succeeded with reducing energy consumption, to what extent is not mentioned though.

"We have, as a company, set damn tough targets in the long term on energy consumption. [...] on our internal goal, we have looked at how much energy we consume per square meter. [...] the measure we use internally is total purchased energy, which is the facility electricity, household electricity, and heating. Energy saving means that we, as individuals, must reduce our energy consumption." (Expert 3)

CSB set targets of reducing their energy consumption which they measure as total energy consumption per square meter. Included in this is facility and apartment electricity and heating. In this measure individual energy savings are not measured but only the total energy savings.

"One of the biggest energy savings we have done was to build new apartments that used the existing systems, which improves the result of energy usage per apartment in kWh/m^2. [...] it is important to see what we can achieve, we want to reduce the individual consumption, so we have to focus on that. [...] our influence on the behaviour of residents, I believe, is quite limited, we live in a soft world where we don't force someone to do something. But in a upcoming crisis that is increasing in probability, it will we required that you are not as soft in order to bring about changes." (Expert 3)

With the use of this measure of energy consumption per square meter they reduced their energy consumption whey they built new apartments which used existing systems. Although, Expert 3 seems to believe that they need to reduce the individual consumption and focus on that. However, he seems to think that they cannot influence the residents' behaviour being soft as they are today. It seems like Expert 3 believes that there is needed stricter rules in order to influence behaviour.

"I believe that property owners must be those who drive and introduce energy-efficient products. There are already a lot of products that says to reduce energy consumption, but how do you know they actually are better. [...] many products don't work, and you have to be incredibly observant when looking at new technology. You have to find these genius products that actually work." (Expert 3)

Expert 3 believes that property owners must be the ones who drive and introduce energy-efficient products. Despite the mentioned importance of that property owners must introducing energy-efficient products, it rather seems like they are late adopters of technology. He seems sceptical of how well these energy-efficient products work and it seems like they are waiting for technology to be better before they introduce it in their building or apartments.

"One of the things I noticed five or six years ago is the radiator system and warm water systems. How well were they actually installed? Not very well it was shown. They were installed so that the water which should come from above was coming from below which resulted in maybe 40 percent of capacity. [...] it's the KV-value which is calculated by consultants before installation which they get wrong and varies making it too cold or too warm in the apartments. This happens even today, we reviewed all installed radiators in a

newly built building and 30 percent were faultless and the rest had all possible errors. We have now included this in our building standards to get it right from the start."(Expert 3)

It seems like even if you hire people to do installations it is important that you make sure that the installations are done correctly so that you do not lose capacity due to errors.