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The impact of grid tariffs based on demand charges

Torleif Møretrø Moen

Master of Energy and Environmental Engineering
Submission date: June 2018
Supervisor: Gerard Doorman, IEL

Norwegian University of Science and Technology
Department of Electric Power Engineering

Title: The impact of grid tariffs based on demand charges

Student: Torleif Møretrø Moen

Problem description:

NVE has purposed to use grid tariffs based on demand subscription and overconsumption. This is expected to reduce the load peaks and therefore have an impact on system operation. The goal for the thesis is to analyze how the load can change, establish load profiles based on these assumptions, and simulate these by using the EMPS model with the data set 2030.

The following should be done:

- Make assumptions about demand tariffs (energy fee, excess demand fee, subscription fee, excess demand period), based on NVE's report (1).
- Calculate optimal subscription for individual customers under different assumptions based on data from household consumers.
- Calculate the resulting sum demand when customers are trying to move all their consumption
- Use this material to model consumption in the EMPS model, by using the firm power profile.
- Create comparable duration curves, and sum profiles for Norway and analyze how the overall demand is affected.
- Conduct relevant comparative calculations with the EMPS model for 2030.

Responsible professor: Gerard Doorman, IEL
Supervisors: Ivar Husevåg Døskeland, Statnett SF
Lasse Christiansen, Statnett SF

Abstract

In recent years, there has been an increase in power consumption for the consumers in the distribution grid. The consequence of this, combined with the consumers being inelastic, has forced the distribution system operators and transmission system operator to invest in the power grid system. To delay or scrap the investments, the Norwegian Water Resources and Energy Directorate (NVE) has proposed to change the current grid tariff, the energy tariff, to a new power based grid tariff named the subscription tariff.

In this thesis, an analysis of the subscription tariff is presented. Also, an analysis is conducted to find the ideal excess demand with the other parts of the subscription tariff given. Two alternatives for the subscription fee is then presented, and the excess demand fee is found for both of these. Further, an analysis is conducted on each alternative, and the ideal subscription fee is chosen to be 60 [NOK/kW/month] based on the analysis, and is used subsequently throughout the thesis. The ideal subscription tariff is then applied to move the consumption for each consumer. A reduction of 6.35% between the original and moving scenario is obtained.

The reduction is then used for further analysis with the EMPS model. The firm power profile - "fastkraftprofilen"- is used to gain a similar decrease in general supply for the EMPS model. To achieve 6% reduction in peak load, the profile is flattened out with 40%. An analysis of the EMPS model is then performed, where two scenarios are presented, the original EMPS firm power profile and the 40% reduced firm power profile. The analysis concludes that the peak is reduced by 6%, which is the same as for the load data set. For the socio-economic perspective, the moving of the consumption gives a surplus for the whole system, while for Norway there is a loss. This is due to the producers losing more than the consumers are gaining. The thesis also follows the change in economic and demand for a consumer, where the reduction in grid tariff is -10% for all consumers when moving the consumption.

Sammendrag

Som en konsekvens av at forbrukerne i distribusjonsnettet er både inelastiske og har en økning i effektforbruk, må distribusjonssystemoperatørene og transmisjonsystemoperatøren investere i kraftnettet. Norges vassdrags- og energidirektorat (NVE) har forslått en løsning for å enten forsinke eller ikke investere i nettet, som innebærer å bytte fra den nåværende energitariffen til en ny effektbasert tariff - abonnementstariffen.

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Denne oppgaven presenterer en analyse av abonnementstariffen. Flere metoder er brukt for å finne den ideelle abonnementstariffen, og en analyse er utført for å finne det ideelle overforbruksleddet, hvor de resterende delene av tariffen er gitt. I tillegg gis det to alternativer for abonnementsprisen, hvor overforbruksleddet er funnet for begge disse. Videre følger en analyse gjort for å finne det beste alternativet, der det ble funnet at en abonnementspris lik 60 [NOK/kW/måneden] gir det beste resultatet. Dette resultatet er brukt videre i oppgaven. Forbruket for hver kunde blir så flyttet for å simulere kunder som prøver å oppnå et forbruk likt sitt optimale abonnement. En reduksjon på 6.35% oppnås mellom det originale og flytte-scenarioet i høylasttimen.

Reduksjonen funnet i flytteanalysen blir videre brukt i Samlastmodell-analysen. Fastkraftsprofilen er brukt for å oppnå en lignende reduksjon i alminnelig forsyning for Samlastmodellen. Videre er en analyse av Samlastmodellen utført, hvor to scenarioer presenteres; den originale fastkraftsprofilen i Samlast mot den endrede fastkraftsprofilen som skal gi 6% endring i last. Analysen konkluderer med at forbruket i høylasttimen reduseres med 6% - det samme som i lastdatasettet. I det samfunnsøkonomiske perspektivet kan man altså anta at det er lønnsomt å flytte forbruket, men for Norge er det ikke lønnsomt, da produsentene mister mer inntjening enn det konsumentene tjener på endringen av forbruket. Forbrukeren vil oppleve at nettleien har et potensial i reduksjon, der alle kundene i lastdatasettet har en reduksjon på 10%, om de flytter forbruket.

Preface

This Master's thesis is written as a part of the Master of Science programme in Energy and Environmental Engineering at the Norwegian University of Science and Technology (NTNU), spring 2018.

I would like to thank my supervisors Professor Gerard Doorman, Ivar Husevåg Døskeland and Lasse Christiansen, for their support during the work with the master project, as well as for the valuable suggestions and comments. I would also like to thank Morten Sjaalmo and Jan Erik Brattbakk at Ringeriks-Kraft for providing me with a data set. I would also like to thank Velaug Mook and Håvard Hansen for giving me insight on the new subscription tariff as well as providing me with helpful documents and comments about my results.

Trondheim, June 2018

Torleif Møretrø Moen

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Abbreviations

DSO = Distribution System Operators
TSO = Transmission System Operator
NVE = The Norwegian Water Resources and Energy Directorate
MC = Marginal Cost
AC = Average Cost
Power intensive industry = Kraftkrevende industri
EFO = Elektroforeningen
SF = Subscription Fee
EDF = Excess Demand Fee

Chapter 1

Introduction

This chapter introduces the thesis as a whole. It presents the background and motivation for the thesis and gives an introduction to the new electricity grid tariff purposed by The Norwegian Water Resources and Energy Directorate (NVE). The goal and research questions for the topic are presented, as well as the methodology used for the field of study. It also includes the contributions, related work and lastly the outline of the thesis.

1.1 Background and Motivation

The electricity consumption in Norway is assumed to increase in the coming years, where the increase in household consumption is due to the growth in population and increase in electric heating (11). The household electricity consumption is also assumed to be more energy efficient, but will demand more power (1).

The power distribution grid is built to handle the peak power hours of the year, while the rest of the year most of the capacity of the distribution grid is unused (12). With a higher demand in power, the power grid needs an investment of 140 [bill. NOK] in the coming years (6).

To make the distribution grid use more of the capacity during the year, and to try to delay some of the investments in the power grid. NVE has proposed to change the current grid tariff, energy tariff, to a new grid tariff called subscription grid tariff (1).

The motivation behind this thesis is to evaluate the subscription grid tariff and if the consumers are moving their consumption such that their consumption profile is more flatten out, how will it affect the system and each consumer.

1.2 Goal and Research Question

The goal and research questions creates the basis of this thesis by being the focal points of the study.

1.2.1 Goal

The focus of this thesis is to analyze the potential of the subscription tariff in the power grid. As presented in Section 1.1, the distribution system operators (DSOs) and transmission system operators (TSO) needs to invest in the power grid and one of the reasons is the increase in power demand. By analyzing the potential of the subscription tariff where the consumers are moving their consumption from above their subscription to below their subscription with a restriction time interval of moving the consumption.

1.2.2 Research Questions

Based on the goal of the thesis, the overall questions to answer are:

- Make assumptions about demand tariffs (energy fee, excess demand fee, subscription fee, excess demand period), based on NVE's report (1).
- Calculate optimal subscription for individual customers under different assumptions based on data from household consumers.
- Calculate the resulting sum demand when customers are trying to move all their consumption
- Use this material to model consumption in the EMPS model, by using the firm power profile.
- Create comparable duration curves, and sum profiles for Norway and analyze how the overall demand is affected.
- Conduct relevant comparative calculations with the EMPS model for 2030.

1.3 Methodology

The research methodology used for the master thesis is divided into three parts; the design phase, the implementation part and the analyzing phase. For the design phase, four functions were created using the program MATLAB. The first function is to mold the data set. The second function is used to find the ideal excess fee when known numbers were given. The third function is created to apply the ideal excess fee to get an ideal subscription to each consumer. The fourth is used to move all consumption above subscription, to consumption below subscription. For the implementation part, two alternatives for the subscription fee were analyzed, and an ideal subscription fee was decided. The ideal subscription fee was then used to move the consumption and find the reduction in the peak hour. The reduction in peak load from the third function was implemented into a demand profile called “fastkraft” in the EMPS model. For the analyzing phase, two scenarios were analyzed and compared against each other; the original scenario and the scenario with the reduction in peak load.

1.4 Contributions

This thesis evaluates the subscription tariff and compares it with the energy tariff used today. The thesis compares the subscription tariff with the energy tariff for a sampled group of 125 residential houses and finds the reduction in peak load when moving the consumption for a time interval. The main contribution of this thesis is the analyzing of the hearing document presented by NVE in October 2017 (1). The subscription tariff presented in this hearing document are both analyzed in demand and an economic perspective.

1.5 Related Work

Several analyzes have been done in the field. This thesis is based on one of the analysis, the hearing document by NVE presented in 2017 (1). An analysis performed by THEMA Consulting in 2015, which concluded with that if power grid tariffs are going to be implemented, it is important to take into account when the grid is at its maximum capacity (13). A hearing statement by POYRY, analyzed the new grid tariff proposed by NVE and concluded with that a consumer with an atypical consumption profile, will get a huge increase in grid tariff cost (9). Trønder Energi Nett also had a hearing statement on the subscription tariff, where they recommended NVE to review the proposal. Trønder Energi Nett thinks that its hard for the ordinary consumer to understand what the subscription tariff is and hard to anticipate their grid tariff (14).

1.6 Outline

This thesis is divided into eight chapters, including this introductory chapter. The outline is as follows.

Chapter 2 Presents the background theory about the topics discussed in the thesis, including the power grid, demand response, automatic meter reading, grid tariff, and the EMPS model.

Chapter 3 Presents the data used in this thesis.

Chapter 4 Describes the MATLAB files created to find the ideal subscription fee, ideal excess demand fee, optimal subscription for each consumer, and moving the consumption for each consumer.

Chapter 5 Presents the process of conducting the analysis, as well as the associated results.

Chapter 6 Presents the continued analysis by using the results from Chapter 5.

Chapter 7 Presents the discussion of the work done during the thesis, and explains the choices that have been made regarding the ideal subscription tariff, the socio-economic surplus, the moving of the consumption, and the impact for a consumer.

Chapter 8 Presents the conclusion for the thesis and proposals for future work.

Chapter 2

Background Theory

This chapter introduces the background theory regarding the power grid, as well as the consumption behavior in Norway, and the reason for changing the grid tariff.

2.1 The Power Grid

The Norwegian power grid is divided into two sub-grids, the transmission grid, and the distribution grid. The transmission grid is the grid which moves the high voltage power for large areas, while the distribution grid is the grid which distributes the power to the consumer in the low voltage grid. To operate the power grid, NVE gives out area concession to build and operate a distribution grid with voltage up to 22 [kV] (15). The TSO task is to operate, ensure maintenance, and develop the transmission system. In Norway, the TSO is Statnett (16).

The transmission grid has ongoing monitoring and control of the grid, which makes it possible to follow the load and power flow and find faults in the grid (17). On the other hand, the distribution grid does not have the same monitoring and control as the transmission grid. The rollout of the Automatic Metering Reading device (AMR), will give the DSOs more information about the load and power flow in the grid.

2.1.1 Automatic Meter Reading

The Norwegian government has decided that every consumer in the distribution grid will change their electric meter reader to an AMR by the first of January 2019. The AMR will change how the DSOs gets information from the consumers, and it will give an hourly measurement of each consumers load profile. The AMR is a metering device that reads the users consumption every hour, with a possibility of reading it every 15 minutes (18, § 4-2). The user can read get their load data in two ways, and the first way is to use the implemented HAN-module, which will give the user instant load data, every 10 second

(19). The second way is to get the load data from the DSO. From NVEs hearing document from 2017; they state a new change in The Norwegian regulation on "Økonomisk og teknisk rapportering, inntektsramme for nettvirksomheten og tariffer" (Economic Regulation), where the DSO has to give the information about the consumer's tariff cost to the consumers before 09.00 the following day (1).

Today, the consumers can choose between three different contracts for their electricity price; spot price, variable price, and yearly fixed price. The spot price is now based on the monthly spot price from Nord Pool, and NVE recommends the power companies to use a tool called adjusted feed profile to find the consumption profile for each consumer (20). If the power company chooses to use another feed profile, they are obliged to inform the consumer which feed profile they are using (21). With the AMR, the consumer will have the opportunity to pay for the spot price they use, which will give the consumers an incentive to respond on price variation, and there is no need for the adjusted feed profile (20).

Today, the AMR measures the load with a time step each hour, where the unit of power is energy divided by time, which is the SI units [J/s]. The difference between how the AMR measures and the power unit, the AMR will not show real power [kW] only energy divided by hour [kWh/h].

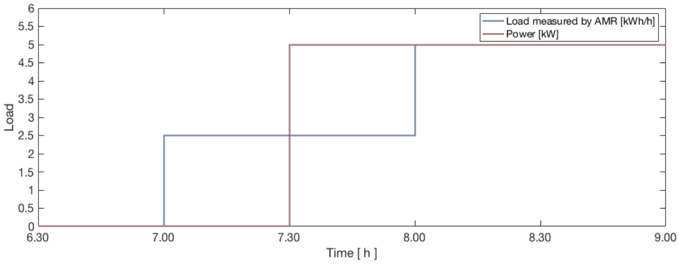

Figure 2.1: The actual power used by a consumer versus the load measured by the AMR.

For example, lets say a consumer has zero power consumption during the night and wakes up at 7.30 AM. Immediately after waking up, the consumer starts some electrical components with a combined power of 5 kW, and the electrical components are on for one and a half hour. The power will start at 7.30 AM and have a load of 5 kW to 9.00 AM, as shown in Figure 2.1. While the AMR will show a power consumption of 2.5 [kWh/h] from 7.00 AM to 8.00 AM and 5 [kWh/h] from 8.00 AM to 9.00 AM, shown in Figure 2.1. The energy consumption will be the same, but as explained above, the displayed power will be different. It might be problematic if the consumer has a high power demand within a short time period. For example, a consumer has a power demand on 20 [kW] for the first five minutes of an hour, and for the rest of the hour, the consumer has 0 [kW]. By this, the consumer will demand 20 [kW] from the power grid, but the AMR measuring will only show that the consumer has a demand of 1.25 [kWh/h]. While this is an extreme example for describing that AMR might not see the actual power, the consumer is charging the grid with 20 [kW] for five minutes, while from the DSOs point of view the power grid is only charged by 1.25 [kWh/h] for the total hour.

2.1.2 Load Aggregation

In the distribution grid, the distribution transformer receives power with a high voltage and transforms it into power with lower voltage. This power is then delivered to the consumers, as shown in Figure 2.2.

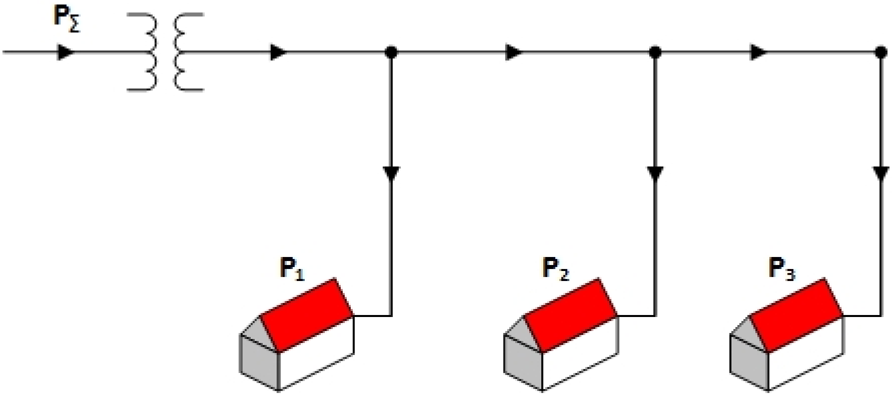

Figure 2.2: A figure representing power going into a transformer, and being distributed to different consumers.

The consumers have their consumption profiles, and their consumption will peak as shown in Figure 2.3. From the high voltage side of the transformer, the load is the aggregation of all the consumer within that transformer - the load aggregation. When a consumer has a peak load, the other consumers might have a low load, but from the transformers view, the load might be average.

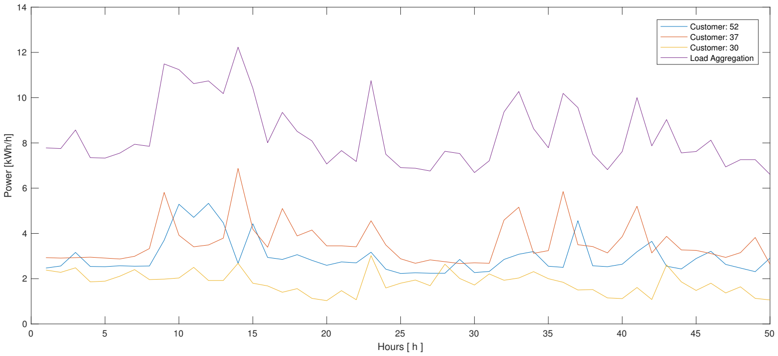

Figure 2.3: An example of load aggregation for three consumers, and their respective consumption.

The power balance for *n* consumers at a given time, without losses, is given by

$$P_{\sum} = P_1(t) + P_2(t) + P_3(t) + ... + P_n(t), \tag{2.1}$$

while the maximum load aggregation is

$$P_{\sum_{max}}(t_{max}) = P_1(t_{max}) + P_2(t_{max}) + P_3(t_{max}) + ... + P_n(t_{max}). \tag{2.2}$$

As described above, and shown in Figure 2.3, the maximum load aggregation is most likely not at the same time as the maximum for each consumer, though it is possible. Therefore the maximum for the load aggregation is either equal to or below the maximum of the load for each consumer. The consumers might have a probability of having their maximum at the same time as the maximum of the load aggregation. A coincidence factor can explain at the maximum of the load aggregation what percentage the individual consumer is at its maximum load:

$$s_i = \frac{P_i(t_{max})}{P_{i_{max}}} \tag{2.3}$$

The coincidence factor s_i in Equation 2.3, is variable from 0 to 1 which explains the factor between the load for consumer *i* at the time instant when the load aggregation is at its maximum divided by the maximum of the load for consumer *i*, where 0 is when consumer *i* has zero load and 1 is when consumer *i* has maximum load. By rearranging Equation 2.3 it can be put into Equation 2.2:

$$P_{\sum_{max}}(t_{max}) = s_1 P_{1_{max}} + s_2 P_{2_{max}} + s_3 P_{3_{max}} + ... + s_n P_{n_{max}} \tag{2.4}$$

Equation 2.4, shows that the maximum of the load aggregation has to be either equal to or smaller than the sum of maximum for each consumer within the transformer.

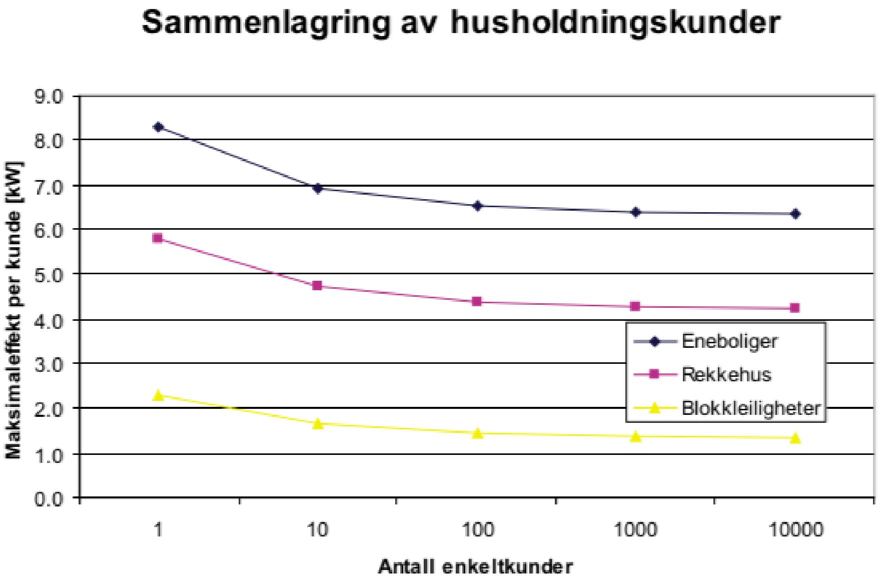

Figure 2.4: The difference in max power per consumer for different sizes of consumers, where the blue line is residential houses, purple line is townhouses and yellow line is apartments (2).

Figure 2.4, shows what happens with the max power per consumer for different sizes of consumers. From Figure 2.4 when the number of consumers reaches 20, the max power per consumer stabilizes. Thereby to get a reasonable result when using load aggregation at least 20 consumers should be looked at, at the same time.

2.2 The Power Consumption in Norway

In 2016, the Ministry of Petroleum and Energy presented Norway's energy policy towards 2030 (22). For the Energy and Power consumption, trends showed that there were more efficient energy consumption, more electricity consumption, and more power consumption (22, p. 121).

The power consumption in Norway can be divided into four sectors; power intensive industry, households and agriculture, commercial, and extraction and industry. The industry in extraction and industry is all industry which is not power intensive industry.

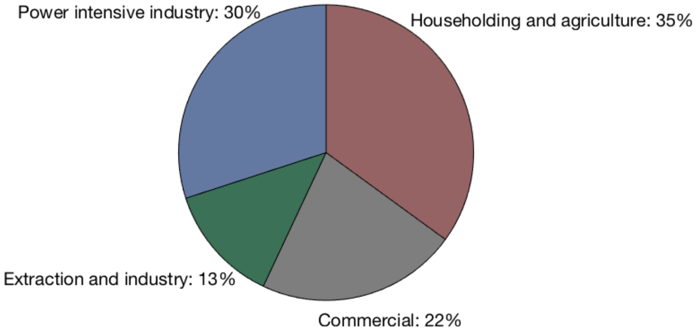

Figure 2.5: Energy consumption in 2016 for the different sectors in Norway (3).

Figure 2.5 shows the representing percentage for each sector of the total energy consumption in 2016 (3). In this thesis, the energy consumption in the Norwegian household is being studied, which is now called household, and it is relevant to determine the household consumption compared to the total energy consumption in Norway.

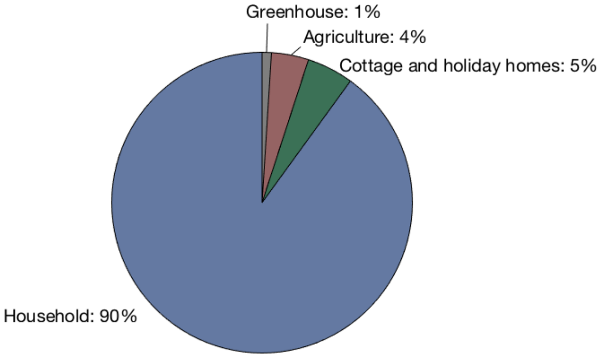

Figure 2.6: The sub-sectors in the households and agriculture sector in 2016, with their respective percentages (4).

Figure 2.6 shows that households stand for 90% of the energy consumption in the sector household and agriculture, which means that households have around 31.5% of the total energy consumption in Norway.

2.2.1 Utilization Time for Electrical Load

The utilization time for peak load in residential households is researched on. The definition of utilization time for peak load is:

$$T_b = E_{year} * P_{peak} \tag{2.5}$$

Equation 2.5 is the utilization time for peak load, T_b. E_{year} is the annual consumption of energy, while P_{peak} is the peak load for year. For a residential house, SINTEF has found it to be 1251 [hours/year] (8).

2.2.2 The Consumption Behavior for Households

The energy consumption for households has increased over the last years, as shown in Figure 2.7. Which also shows that even though the trend displays an increase in consumption for households, there is a significant difference from year to year. The reason for this is that 57% of energy consumption in households goes to space heating, which means that the difference in temperature from year to year is essential for the difference in consumption for households (23). There is a broad field of study for the outdoor temperature dependent consumption, one of the concludes that the outdoor temperature is a significant factor for the consumption behaviour for consumers (23). Since the outdoor temperature is such a significant factor, its hard to compare the consumption year to year, thereby a figure which adjusts the consumption such that the consumption is independent of the temperature. The temperature adjusted consumption has stagnated since the year 2000 (23).

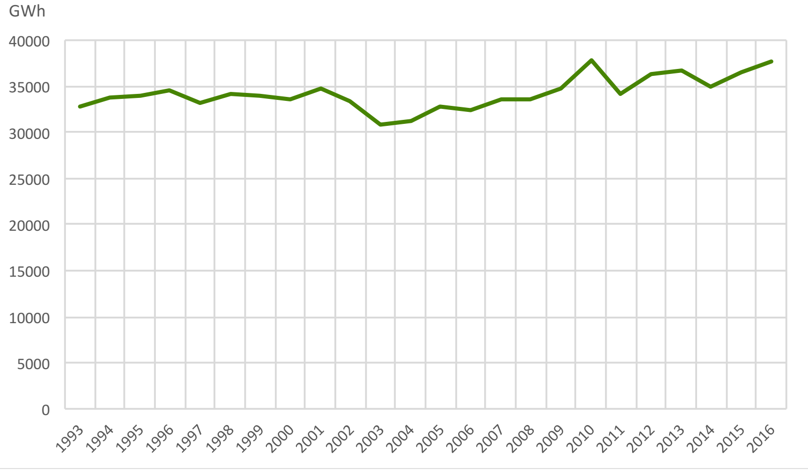

Figure 2.7: The electricity consumption for households (5).

Figure 2.7, shows that the consumption is increasing for each year. Which can be explained by different factors, one factor is that there is an increase in households and another might be that the consumers are increasing their consumption. When looking at

Figure 2.8, which shows the consumption of households per house, the trend indicates that the consumers are decreasing their consumption.

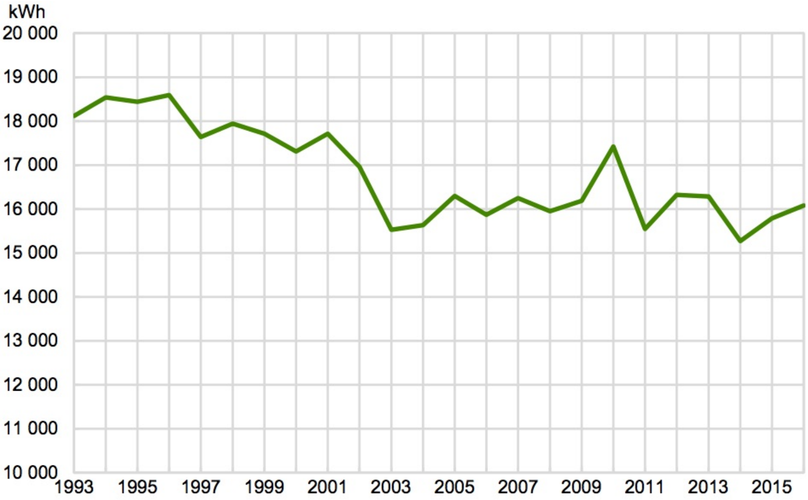

Figure 2.8: The electricity consumption of households per house (5).

While the trend of energy consumption is decreasing per household, the power consumption is increasing, as shown in Figure 2.9.

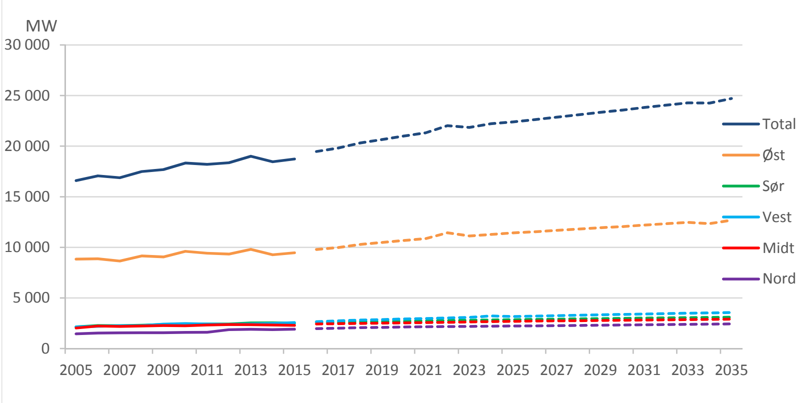

Figure 2.9: The power consumption for each region and total in Norway (6).

2.2.3 Elasticity for General Supply

The Norwegian consumers are very inelastic, according to a 2011 report from Statistic Norway. The report describes that when the spot price from month to month is increasing by 1%, the consumption for general supply is decreasing by 0.05% (24). The ECON report from 2004 shows that for a short period, the consumption is decreasing by 0.22% if the spot price is increasing by 10%. While for the long term, the consumption will decrease by 0.57% if the spot price increases by 10% (25).

2.3 Demand Response

The demand response is defined as the consumer's ability and willingness to change or reduce their energy consumption for a period (26). In the power grid, there needs to be an energy balance at all times, which means that the production and consumption needs to be equal.

2.3.1 Consumer Flexibility

As seen in Section 2.2.3, the potential of the consumer flexibility is large as the consumers are very inelastic. The consumer flexibility in the Nordic region has a potential of 4000-7000 MW, of that Norway has a potential of 1400-3400 MW, which is mostly heating and electrical vehicles (27). In the distribution grid, the consumer flexibility might able to reduce the peak load in local points, which can postpone or scrap new investments in the grid (26).

2.3.2 Different types of Consumer Flexibility

The different types of Consumer Flexibility is shown in Figure 2.10:

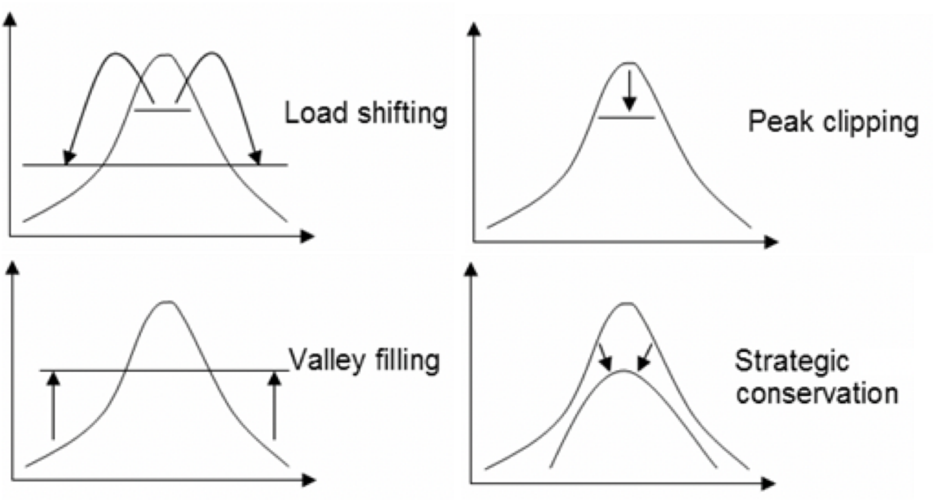

Figure 2.10: Different types of consumer flexibility (7).

From Figure 2.10, the load shifting is when the consumer is moving their load from a high price period to a low price period. The peak clipping is where the consumption is reduced at a given period. Valley filling is where the consumption is increasing during a low load period. Strategic conservation is where the consumption for the whole period is reduced to be more energy efficient (7).

2.3.3 The Consumers Willingness to Change their Consumption

The consumer behaviour is vital to understand how the consumers can move or change their consumption as described above. The consumer behaviour is the willingness of the consumers to change their consumption profile. A recent survey performed by Sentio Research Norge AS, created for NVE, shows that 1/3 of the consumers in the survey were willing to change their consumption from day to night to decrease their electricity bill (28). 77% of the consumers were also interested in their consumption profile and while 71% of the consumers were interested in information on how to reduce their electricity bill (28).

2.4 Investments in the Power Grid

The power grid is built to withstand peak load during rationing hours. As described in Section 2.2.2, the power consumption is increasing, which means that the TSO and the DSOs have to upgrade the power grid within the next years. In 2016, NVE presented a report which showed that in the next ten years, the DSOs and the TSO needs to investment 140 [bill. NOK] in the power grid (6). The investment will increase the grid tariff by 25% to 30% (29).

2.4.1 The Different Cost for Investment in the Power Grid

To invest in the power grid several factors has to be taken into consideration. Eivind Solvang explains that there are several steps for planning the investment (8):

- Establish Premises
- Determine the load and production
- Determine the need and solution options
- Conduct technical analysis
- Determine the costs
- Conduct economic analysis
- Make a overall assessment

This thesis will assume the at the four first steps is determined. The interesting factor for this thesis determines the costs and the economic analysis. To determine the costs, several points can be made; the investment cost, operating and maintenance cost, the loss cost, grid losses and cost of energy not supplied, and environmental costs.

In this thesis, the interesting factor is the cost of upgrading or investing in the power grid.

Which means that the focus here will be determine the costs and the economic analysis. A line in the power grid has a maximum power it can deliver determined by the cross-section of the line. The investment cost for a line can be written as:

$$K_L = (k_0 + k_{tv} * A) * L \tag{2.6}$$

The investment cost for a line as shown in Equation 2.6, K_L, is determined by; k_0 [NOK/km] the cross-section independent cost, k_{tv} [NOK/km/mm^2] the cross-section dependent cost, A [mm^2] the cross-section and L [km] the length of the line (30). The cross-section independent cost is a cost which is independent of the size of the cross-section, this is the cost for building the line and the other cost than the cross-section.

The loss cost is determined by the losses of the line times a factor for the loss cost.

$$K_{\Delta P} = K_{pekv} * 3 * I^2 * \rho * \frac{L}{A} \tag{2.7}$$

The loss cost, as shown in Equation 2.7, is determined by the: K_{pekv} [NOK/kW] is the Capitalized equivalent cost of power losses. I, the current in the line, ρ [Ω*mm^2/km] the specific resistance, L the length of the line, and A the cross-section of the line. As seen in Equation 2.7, the cross-section of the line determines the size of the loss cost (30).

For a narrow cross-section, the higher the peak load, the higher the cost in the grid.

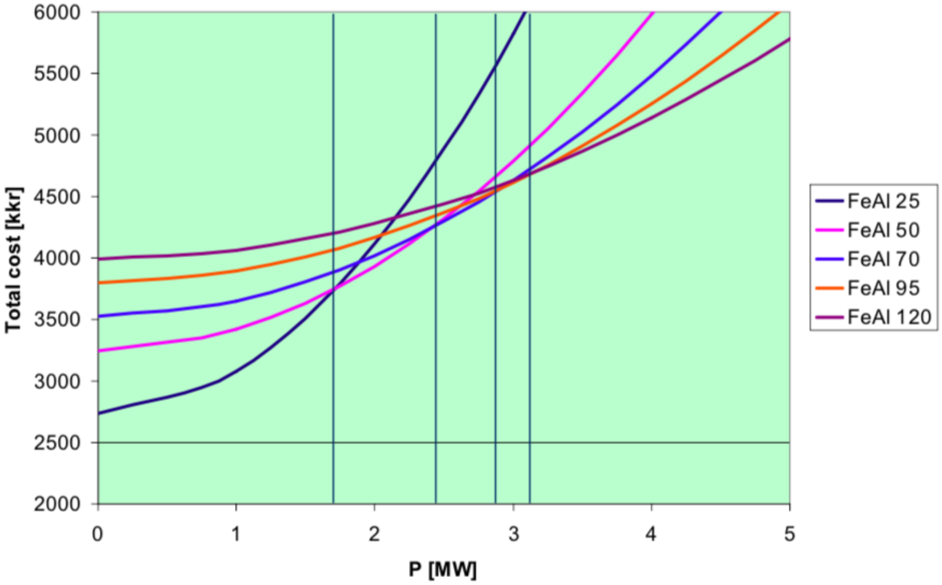

Figure 2.11: Different cross-sections for investing in a new 10 km line (8).

As seen in Figure 2.11, the total cost of investing in a new line is determined by the peak load. If the peak load is low, a narrow cross-section is optimal, while if the peak load is high, a thick cross-section is optimal.

2.5 Natural Monopoly in the Power Grid

The definition of a natural monopoly is that it is less costly to produce a unit of a homogeneous product for one firm than for several firms (31).

In a natural monopoly, the marginal cost (MC) is lower than the average cost (AC). While the optimum for social welfare is that the price equals MC, but in a natural monopoly the total cost will not be covered if the price is equal to marginal cost, which means that the firm will lose money if the price is equal to MC. If the price is equal to AC, there is a loss in social welfare. The losses in social welfare are caused by the inefficiencies, market and X.

Market inefficiency

Since there is only one contributor to the product in the market, the firm can optimize its own profits by overpricing the product. Socio-economic losses are caused by overpricing the product. These losses are called market inefficiency.

X-inefficiency

The X-inefficiency is based upon the theory that the monopolist does not have any initiative to reduce its cost to make the product more cost-efficient. The reason for this is that there are no competitors to make the product more cost-efficient and the cost is paid for by the consumer.

The book "Power system Economics - the Nordic Electricity Market" lists up three factors that can cause X-inefficiency (32, p. 317).

- **Wrong Scale** - The firm is not the optimal size it is either too small or too big.
- **Technical inefficiency** - The firm use too large quantity of production than needed.
- **Cost-inefficiency** - Does not minimizes the cost of the production.

2.5.1 Natural Monopoly in the Norwegian Power Grid

The distribution grid is a natural monopoly, from the definition of natural monopoly which is described above, it is not economically viable to have parallel distribution grids in one area to create a competitive market for distributing electricity (33). While it should not be parallel distribution grids in one area, there can be several DSOs in a market which is operating in different geographical areas inside the market (32, p. 312).

To solve the overpricing in the distribution grid, the Norwegian government introduced a regulation model in 1997. The regulation model has changed over the years (34). The last time the regulation model was modified was in 2007. The regulator, NVE, sets a maximum revenue cap for each DSO, the DSOs can make cost savings to gain a higher profit (32, p. 324).

$$R_t = (1-\rho) * K_t + \rho * K_t^* \tag{2.8}$$

The maximum revenue cap is based on several factors, ρ is the size the cost norm represents the maximum revenue cap, ρ is a number between 0 and 1. The inflation-adjusted cost base, K_t, is based on historical cost from t-2 and are inflation-adjusted. K_t^* is the cost norm the DSO based on historical data (35). As Equation 2.8 shows, the larger ρ is, the more dependent the maximum revenue cap is of the cost norm, today ρ is equal to 0.60.

To decide the inflation-adjusted cost base, several factors are taken into account:

$$K_t = (OM_{t-2} + CES_{t-2}) * \frac{CPI_t}{CPI_{t-2}} + P_{loss} * C + D_{t-2} + IR_{t-2} * r_{NVE} \tag{2.9}$$

As Equation 2.9 shows, the inflation-adjusted cost base is based on,OM which is the operation and maintenance and also includes payments to consumers with a specially long interruption and individual cost of energy not supplied deals with consumers. CES_{t-2} is the cost of energy not supplied, without the individual deals which are in operation and maintenance. CPI_t is the consumer price index, which is to compensate for the inflation. P_{loss} are the losses from transporting the energy. C is the reference price of power at that particular geographical area. D_{t-2} is the annual depreciation, IR_{t-2} is the rate of return and r is NVE's reference interest (35).

The cost norm, K_t^*, is a general requirement for all DSOs and an individual requirement based on efficiency measurement by Data Envelopment Analysis. The measurement by Data Envelopment Analysis is to benchmark the efficiency of the DSO by comparing it to the best comparable DSO (35).

The DSOs also have an allowable income that the regulator, NVE, sets (35). If the income becomes higher than the maximum allowable income by NVE, the consumers in that geographical area are going to get paid back for the difference. If the income becomes negative from the difference between the actual income and the allowable income, the DSO can increase the grid tariff cost (36, § 7-5).

2.6 Grid Tariff

To cover the cost of maintaining and operating the power grid, the consumers pay a grid tariff to the DSO that is operating in their geographical area (33). The DSOs sets the grid tariff prices for each own geographical area (37).

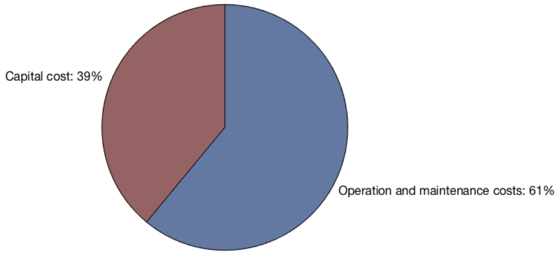

Figure 2.12: The total cost in the distribution grid (9).

Maintaining and operating the power grid is divided into two under categories, capital cost, and operation and maintenance cost. From Figure 2.12, the capital cost is 39% of the total cost. The capital cost consists of depreciation and the normal rate of return on accounted value of grid infrastructure. The operation and maintenance cost includes of operation and maintenance, which is just under 80% of the operation and maintenance cost, grid losses and cost of energy not supplied, which is 7% and 14%, respectively (9).

To cover the cost of maintaining and operating the power grid, the DSOs charges each consumer within their geographical areas with a grid tariff. NVE lets the DSOs choose their grid tariff price to cover their cost (35). The current grid tariff is based on that the consumers are first divided by their coupling point (36, § 13-1). If the consumers are coupled to the transmission grid and are a power intensive industry, then the consumer is dealing with the TSO, Statnett. While if their coupling point is in the distribution grid, the DSOs can choose how their grid tariff in their geographical areas are formed (38). Most of the DSOs differentiate the consumer in three sub-categories; households, leisure home, and commercial. The consumers with a fuse that is higher than for example 80 [A] at 230 [V] or has a yearly consumption higher than, e.g. 100 000 [kWh] usually has another part in the tariff which is the power cost [NOK/kWh/h]. For the consumers with a normal consumption and fuse, the grid tariff is divided into two parts, which is an energy cost [NOK/kWh] and a fixed annual cost [NOK/year] (36, § 14-2). In this thesis, the focus will only be households a normal consumption and fuse.

2.6.1 Energy Tariff

Since this thesis only will focus on households, the only tariff will be the energy tariff. The energy tariff consists of two parts, energy cost and fixed annual cost.

Energy Cost

The purpose of the energy cost is to make the consumer pay for their MC they cause by using power from the grid. The energy cost is reflected by paying for the transfer for current and the loss of power, which happens when power goes through the grid.

Fixed Annual Cost

The fixed annual cost covers all fixed cost in the grid and consumer-related cost, such as measurement, calculations, billing, etc (39).

Pros and Cons with the Energy Tariff

As described in Section 2.1, the distribution grid is built by estimating the top consumption for each geographical area and as the yearly energy consumption per household is decreasing since its top year 1996, as seen in Figure 2.8. Since the power consumption is increasing, the consumers are using more power consuming household applicants, and the arrival of the electric vehicle also has an impact of the power consumption.

Calculating the Energy Tariff

The energy tariff is quite simple to calculate, it is only based on two parts. The energy tariff is

$$C_E = C_{fixed_e} + C_{energy_e} * E \tag{2.10}$$

Where the C_{fixed} [NOK/year] is the annual fixed cost, C_{energy} [NOK/kWh] is the energy cost, and E [kWh] is the annual consumption of energy.

2.6.2 Subscription Tariff

The new tariff purposed by NVE is the subscription tariff (1). The new parts of the subscription tariff is trying to solve the issue explained in Section 2.2.2 as the distribution grid is being used inefficiently. The new parts; power capacity and excess demand, are trying to solve the inefficiency by adding another cost to penalize to consumers with high peaks in their consumption and a varied consumption profile. By penalizing the consumer for having high peaks, the consumers can get a understand on how their demand will affect the power grid.

Purpose behind changing the tariff

As the grid gets more and more energy efficient but requires more and more power, the capacity cost purpose is to give the consumers an incentive to reduce their peak power, such that their consumption is within their capacity. If the consumers reduce their peak power, a delay or stop future investments in the power grid can be achieved.

The Different Parts of the Subscription Tariff

The new grid tariff, subscription tariff, has two new components, a subscription fee [NOK/kW/year] and an excess demand cost [NOK/kWh/h]. The new grid tariff cost is then calculated as follows:

$$C_S = C_{fixed_S} + C_{subscription} * P + C_{en_S} * E + C_{ex} * E_{ex} \tag{2.11}$$

The total cost for subscription tariff C_S is based on these four components shown in Equation 2.11. C_{fixed_s} [NOK/year] is the annual fixed cost for the subscription tariff, $C_{Subscription}$ [NOK/kW] is the cost per power which the consumer subscribes to, C_{en_S} [NOK/kWh] is the energy cost for the subscription tariff and C_{ex} [NOK/kWh/h] is the excess demand cost. The other factors are: P [kW] is the power which the consumer subscribes to, E is the annual consumption and E_{ex} [kWh/h] is the excess consumption throughout the year.

The purpose of these different parts is to cover different costs for the DSO. The purpose of the energy cost, C_{en_S} is to cover the short-term marginal cost for the power grid (1). The purpose of the fixed cost, C_{fixed_S}, is to cover the consumer related cost and maintenance cost. The purpose of the power capacity cost, $C_{Subscription}$, is also maintenance cost and new investment cost, the purpose of the excess demand cost, C_{ex}, is also to cover the new investments for the power grid (9).

In the hearing document from 2017, NVE states that the new regulation should be included in the economic regulation. The new regulation is that the consumers DSO have to guide the consumers about which subscription to choose, such that their grid tariff cost is lowest. While the DSOs can guide the consumers to the subscription with the lowest cost, the consumers can decide which subscription to subscribe to (1).

2.6.3 The Politics behind the new Tariff

In the first hearing document from 2015, NVE purpose that the grid tariff should be changed from energy tariff to power tariff. The reason for changing the tariff is to get a more efficient and smarter utilization of the power grid, in which the DSOs might reduce their future power grid investments and by that reducing the consumer's grid tariff expenses (38). Better utilization of the power grid is the foundation behind NVE proposal to change the grid tariff from energy to subscription. The rollout of the AMR for consumers in the distribution grid helps with the better utilization of the power grid. The AMR, as explained above, can read the consumption every hour, and by that, the DSOs can get a more detailed load profile from each consumer (1).

Complaints on Changing the Grid Tariff

There have also been complaints about the consumers changing the energy tariff to a power tariff. In Hvaler, consumers complaint to NVE about the increase in grid tariff, which a consumer had 6000 [NOK] increase from the energy tariff to the maximum power tariff. One of the complaints about the increase in grid tariff was that the consumer had no tool to even his consumption profile. Other consumers in Hvaler have also complained, one consumer had to pay 500 [NOK] in grid tariff for a month when he was only at cottage one day (40).

The Reason for the Subscription Tariff

NVE purposed the subscription tariff based on several grounds, one of the grounds were a focus group survey made by "Trøndelag Forskning og Utvikling" on behalf on NVE (41). The focus group survey found that consumers are finding it challenging to understand the difference between energy and power and that few consumers understand how much power their residential house needs. The consumers in this survey wanted to have flexibility and available to influence their own grid tariff cost while they wanted a grid tariff which were predictable. The survey also had the consumers give an option on which grid tariff they thought were the best. The survey showed that the consumers preferred the subscription tariff, though the survey stated that it should not be an absolute answer.

2.6.4 Hearing Statements on the Hearing Document from 2017

The hearing statements on the hearing document from 2017, was negative to the change to the subscription tariff, A review by Elektroforeningen (EFO), showed that 27 of 30 organizations which sent hearing statements were negative on the subscription tariff (42). While most of the organization were positive to a change in grid tariff, they felt the subscription tariff were not the right one (43).

NTNU explains that a static subscription tariff has its weaknesses, where the excess demand fee is a year around cost, while the grid is only at its max capacity a couple of hours in the year (44). NTNU purpose that instead of a static subscription tariff, a dynamic subscription tariff should be used. The dynamic subscription tariff will switch on when the grid is at its maximum capacity (45).

2.7 EMPS model

The EFI's Multi-area Power Scheduling (EMPS) is a multi-area model that tries to mimic the Nordic power system interaction with the power market and the power grid. SINTEF and Powel have developed the EMPS model. The model has been in development since the 1960's with planning and optimizing the hydro production being the the driving force (46). The EMPS model consists of two phases; a strategy phase and a simulation phase. In the strategy phase, the water values are calculated for each geographical area for each week, and an illustration of the geographical areas is shown in Figure 2.13. A SDP calculation requires a substantial amount of computing power, and therefore some simplification has to be made to make the model perform quicker. For the simulation phase, the water values found in the strategy phase are simulated using two steps. The first step is to find the optimal solution for the geographical area model, and the second step is to use a detailed reservoir drawdown to distribute the optimal total production.

The EMPS model are used in Statnett and are the most important model for integrated analyzes of the Nordic power system. The EMPS model are used to make investments, analyzing and keep control over the power market and the power grid. Statnett's EMPS data set has been built up through several years and from several sources. Every year Statnett makes a dataset based for each of the Grid Development plan's scenarios. Together with the data set, the dataset which describes today's power grid is being updated. The data set is made by combining these two (46).

2.7.1 Demand in The EMPS model

The demand in the EMPS model is divided into different segments, where the main segments are general supply, industry, and boilers. This thesis will focus on the general supply, which is called "fastkraft" in the EMPS model. The general supply consists of residential houses. For Statnett, the price elasticity for general supply is set to -0.3%, which is based on numbers from the report "Kortsiktig prisfølsomhet i alminnelig forsyning" by ECON (25).

The Firm Power Profile

The firm power profile, "fastkraft" profile, is a profile for the general supply in the EMPS model. The purpose of the model is to segment the time resolution on a weekly basis to an hourly basis for the general supply in the EMPS model. The profile has a prewritten data for each hour in a particular week based on historical data.

By having the prewritten data for each hour, the hourly load can be easily found. The given weekly consumption is divided by 168, which is the number of hours in a week, $E_{hourly,avg} = E_{Weekly}/168$, the hourly average consumption becomes the reference consumption for that particular week. The reference consumption is given as 1, which means that it is $E_{ref} = E_{hourly,avg}/E_{hourly,avg}$. For the other hours, Statnett has produced a dataset for every hour in every week on a yearly basis, based on historical data. If hour i, has the same consumption as the hourly average for week j, it will be written as 1.

$$E_{ref,i,j} = \frac{E_{hourly,i,j}}{E_{hourly,avg,j}} \tag{2.12}$$

From Equation 2.12, the reference consumption, $E_{ref,i,j}$, for hour i in week j, is the hourly consumption, $E_{hourly,i,j}$, for hour i in week j, divided by the average hourly consumption, $E_{hourly,avg,j}$, for week j. The reference consumption for each hour in each week is already found from historical data by Statnett, and the sum of the reference consumption divided by the number of hours in a week is equal to 1. If combining all the reference consumption for each hour and dividing it by the number of hours of the week, the historical data is made such that it should be equal to the average hourly consumption.

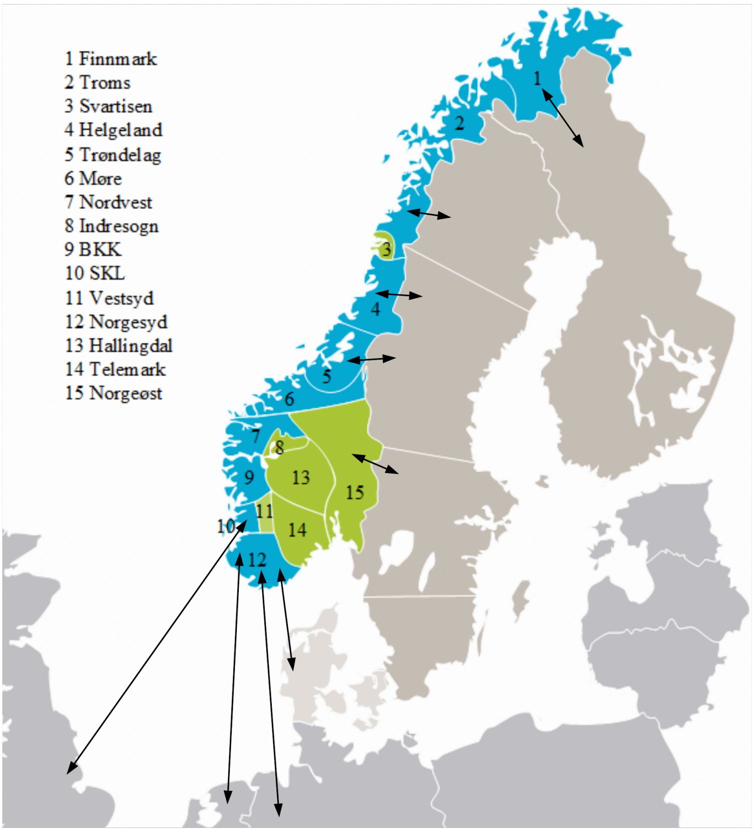

Figure 2.13: The EMPS partial areas in Norway with border connection (10).

Chapter 3

Data

This chapter presents the sources of data used for gathering the information used in this thesis.

3.1 The Load Data

The load data are gathered from Ringeriks-kraft. The time resolution on the load data is hourly. The load data is given in kWh/h and is rounded to the closest 10 Watts. The time period is from the first hour of 01. January 2017 to the last hour of 31. December 2017. The number of different consumers is 475, these are seen as measuring points in the load data. The measuring points are unique for each consumer.

The load data are anonymous and is only specified by their measuring point and facility information. The measuring points are divided into different subcategories based on their facility information. The original groups for the subcategories have been modified to such that the groups for the subcategories are more defined. The different subcategories are residential house, house, apartment, cottage, commercial, and public building.

This thesis will focus on load data based on the subcategory residential house, which is 164 different measuring points. To get a fulfilling answer, the consumption data for these measuring points have to be complete for the whole time period. When taking this restriction into mind, the size of the measuring points is reduced to 125 unique measuring points which have the subcategory residential house and has complete consumption data for the whole time period. From Section 2.1.2, the number of consumers should be above 20 to get a reasonable result, with 125 consumers the load data fulfills this statement.

3.1.1 The Daylight Saving Time

The daylight saving time is clock-timed based scheme that sets all the watches forward by one hour to utilize the brightness of the sun. The daylight saving time is used in Norway and is happening at 02.00 the last Sunday of March, in 2017, the last Sunday of March was 26. of March, which will be hour *2019* of the year. The daylight saving time will affect the consumption data since it will be shown in the data as it is not removed from the load data set.

3.2 Numbers used in the Grid Tariffs

The grid tariffs used in this thesis are based on NVEs hearing document from October 2017 (1). The hearing document has calculation examples, which is were the numbers for the two grid tariffs are taken from.

3.2.1 The Energy Tariff

As explained in Section 2.6.1, the energy tariff is divided into two parts:

Table 3.1: The numbers used for the energy tariff in this thesis.

	Cost	Unit
C_{en_e}	0.194	[NOK/kWh]
C_{fixed_e}	1749	[NOK/year]

The numbers are shown in Table 3.1, will be used in the calculations for the energy tariff for each consumer.

3.2.2 The Subscription Tariff

The subscription tariff in this thesis are using the numbers from the hearing document from 2017, but with an alteration, in the hearing document the excess demand fee, now called EDF, and subscription fee, now called SF, are given. This thesis will first try two alternatives for the SF and use the SF to find the ideal EDF such that the DSOs have as little change in income as possible. The numbers given for the subscription tariffs are shown in Table 3.2:

Table 3.2: The numbers used for the subscription tariff in this thesis.

	Cost	Unit
C_{en_S}	0.05	[NOK/kWh]
C_{fixed_S}	1060	[NOK/year]

3.3 The EMPS data

For the EMPS model, the data set has to be decided.

3.3.1 The "2030 basis (sbds_053b) 168b EMPS" data set

The "2030 basis (sbds_053b) 168b EMPS" dataset is a dataset which is based on 30 years from Statnett. The time resolution on the load data is hourly. The load data is given in GWh. The time period is from the first hour of the first week of 1988 to the last hour of the last week of 2016. For each year the dataset is divided into 52 weeks, and for each week there are 168 hours. By combining all hours the hours in the dataset will be equal to 253 344. The "2030 basis (sbds_053b) 168b EMPS" dataset is the dataset which this thesis is using when using the EMPS model.

Chapter 4

Methodology

This chapter describes the methodology used for gathering the information used further in the analysis. The Methodology will be the design of each MATLAB code which is needed to solve the problem in this thesis and the programs used to analyze the results from the EMPS model.

4.1 Finding the Ideal Excess Demand Fee

As described in Section 3.2, the only component which is not given or chosen is the EDF. The subscription tariff should be equal to today's energy tariff to find the ideal EDF. The reason why they should be equal is that, as explained in Section 2.6, the DSOs have a regulated income from grid tariffs, which means that the DSOs should get the same income for the two tariffs.

$$C_{fixed_e} + C_{energy_e} * E = C_{fixed_S} + C_{Subscription} * P + C_{en_S} * E + C_{ex} * E_{ex} [NOK/year] \tag{4.1}$$

For all consumers, the cost for both tariff in Equation 4.1 should be equal such that the DSOs have the same regulated income.

4.1.1 The Function for Finding the Ideal Excess Demand Fee

The function, "FindingIdealExDFee.m", goal is to find the ideal EDF when the SF is chosen. The focus of this function will be to have the grid cost equal to each other, as shown in Equation 4.1.

The simulation to achieve the ideal excess demand cost should be as short as possible to stop excessive simulation period. A simplification of the Equation 4.1 is used for this purpose, and instead of having the two tariffs equal to each other, the simplification says that the absolute value of the difference between the two tariffs should be less than one percent.

$$\left| \frac{C_{E,tot} - C_{C,tot}}{C_{E,tot}} * 100\% \right| > 1\% \tag{4.2}$$

By using Equation 4.2, the function becomes simpler and can reach the desired solution with a shorter simulation period.

Another method to reduce the simulation period is to decrease to a number of consumers a random sample can be chosen to find the ideal EDF. This thesis will investigate what the correct size of the random sample is for two alternatives.

From the flowchart shown in Figure 4.1, the user are now in Step 1. The user of the function now has to decide two variables, the first is the size of the random sample and the second is the SF. The EDF is set to 0 [NOK/kWh/h]. The subscription steps taken by the function is from 0.5 to 20 [kW].

As seen as step 2 in Figure 4.1, the first step for the function is to calculate the energy tariff. The energy tariff is based on the Equation 2.10 and the numbers used in Table 3.1. Looking at Equation 2.10 the only missing variable in Table 3.1 is the annual consumption of energy, E, which is the consumption data for each consumer, described in Section 3.1, are accumulated into the annual consumption of energy for each consumer, which give E for each consumer. By using Equation 2.10 for all consumers the total cost for the energy tariff is then calculated for all consumers in the random sample.

The ideal EDF is found by using a while-loop, where the statement is 4.2. The basics behind the while-loop are that the loop runs until the statement is fulfilled, as shown as step 3 in Figure 4.1. The while loop will run until the absolute difference between the two tariffs is below one percent. To achieve this, the function starts with the EDF equal to 0.01 [NOK/kWh/h] and starts with the first consumer, consumer i, the function then takes the first subscription k, 0.5 [kW], and goes through the consumption data for consumer i. If the consumption in hour j, is higher than the subscription k, consumer i will have to pay the EDF times the difference between the consumption at hour j and the subscription. The difference between the consumption and the subscription, if the consumption is above the subscription will now be called overconsumption. If consumption is above the subscription, the function will use:

$$C_{i,k,C_j} = C_{i,k,C_{j-1}} + C_{i,en_S} * E(j) + C_{i,k,ex} * E(j)_{i,k,ex} \tag{4.3}$$

For hours where the consumption is not above the subscription, e.g., either on the subscription or below, the function will not use the Equation 4.3, but:

$$C_{i,k,C_j} = C_{i,k,C_{j-1}} + C_{i,en_S} * E(j) \tag{4.4}$$

The C_{i,C_j}, for both Equation 4.3 and 4.4, is the total cost for consumer i with subscrip-

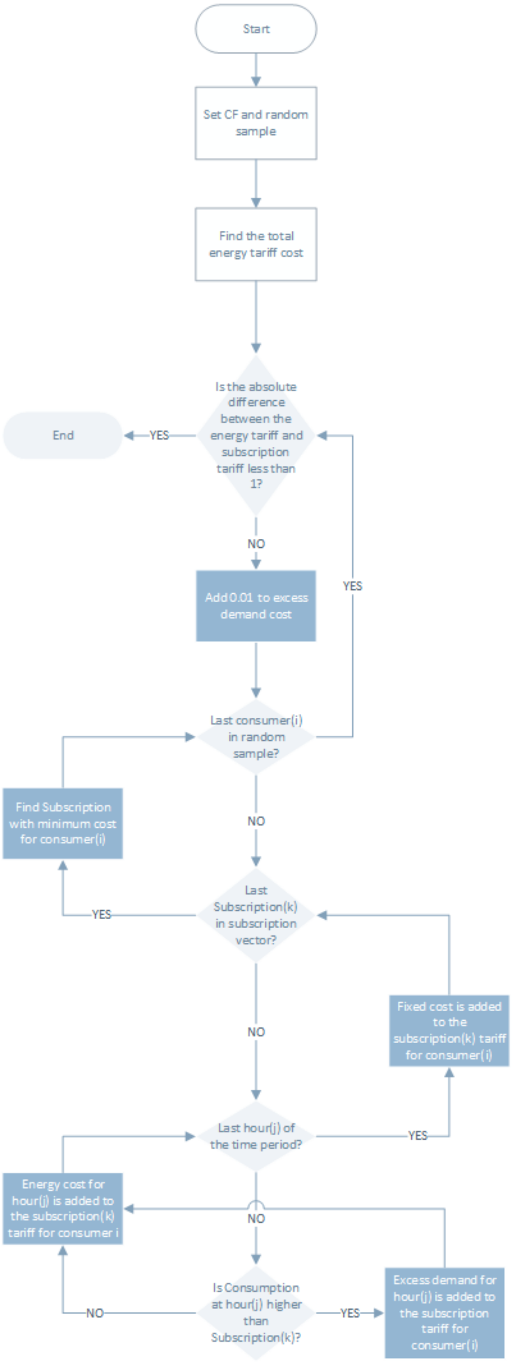

Figure 4.1: The flowchart for the MATLAB function "FindingIdealExDFee.m".

tion *k*, when the function has reached hour *j*, when the function is through the whole time period, hour *8760*, the total cost C_{i,k,C_j} without the fixed annual cost for the subscription tariff, C_{en_c}, and the cost per power which the consumer subscribes to, $C_{Subscription}$.

When consumer *i*, has gone through every consumption data for the consumption period for subscription *k*, the function adds the fixed annual cost and the cost per power from subscription *k*. The fixed annual cost and the cost per power from the subscription is then added to the subscription array, and after that, the function starts over again on the next subscription *k+1*, which is 1 [kW] and finds the cost until all subscription cost till subscription is equal to 20 [kW] is found. When all the subscriptions are found, the function finds the subscription with the lowest cost. The subscription with the lowest cost will be the optimal subscription for consumer *i*. The function does this for all consumer in the random sample and gets a total cost for the subscription tariff. The function then checks if the absolute difference is smaller than one percent. If the absolute difference is larger than one percent, the function adds 0.01 [NOK/kWh/h] to the EDF, and starts at the beginning of the loop and finds the optimal subscription for each consumer with the new EDF. The function adds 0.01 [NOK/kWh/h] to the EDF and starts at the beginning of the loop until the absolute difference is smaller than one percent.

Now the function has found the ideal EDF, and another function is used to find the optimal subscription for each consumer with the ideal EDF.

4.2 Finding the Optimal Subscription for each Consumer

The MATLAB function "OptimalSubscription.m" finds the optimal subscription for each consumer in the load data the same way the MATLAB function "FindingIdealExDFee.m". The only difference between the models is that now the function "OptimalSubscription.m" does not have to find the ideal EDF, thereby the while-loop and the choice of random sample is removed from the function. The Flowchart presented in Figure 4.2, shows how the function "OptimalSubscription.m" behaves. Since the Section 4.1.1 has gone through the concept of how to find the optimal subscription, it will be not presented here.

The optimal subscription found for each consumer is defined as the subscription found in this function with the lowest cost.

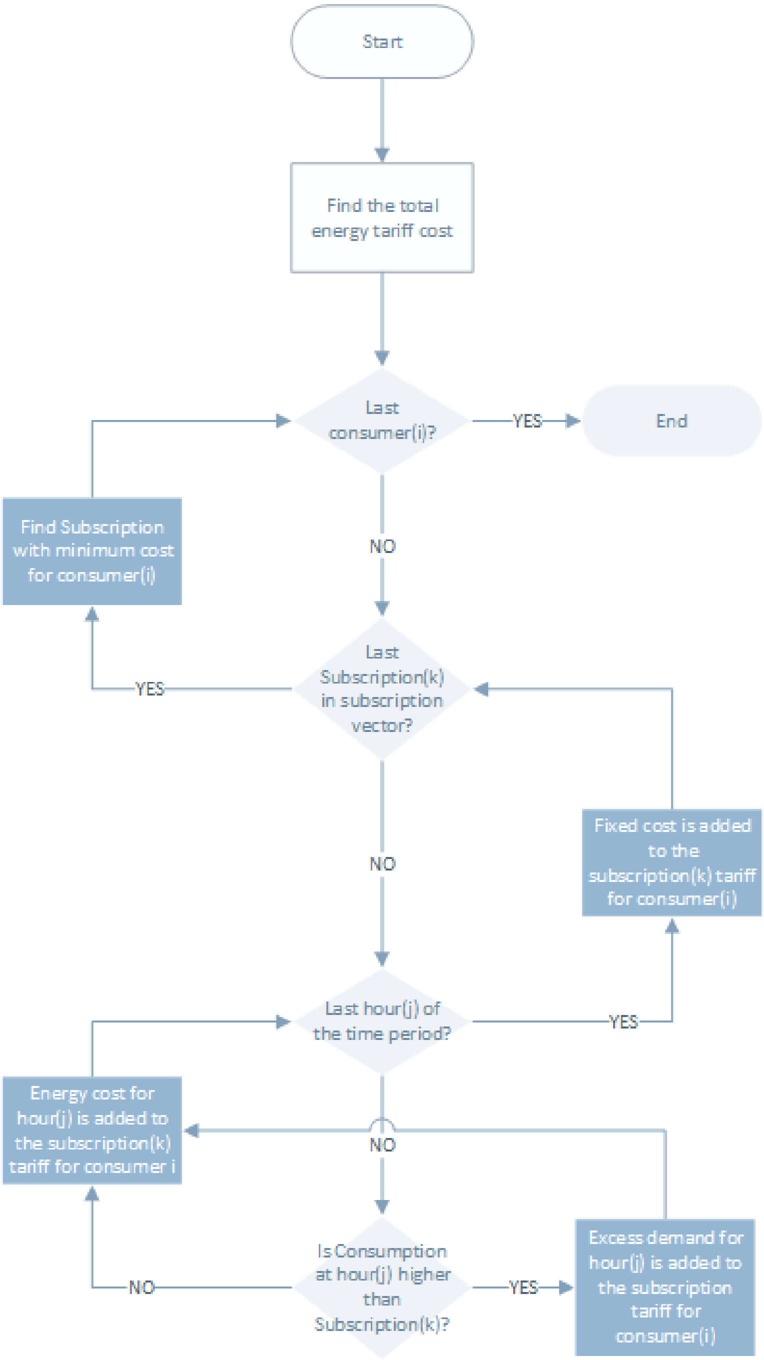

Figure 4.2: The flowchart for the MATLAB function "OptimalSubscription.m".

4.3 Moving the Consumption which is over the Optimal Subscription

The MATLAB function "MovedCons.m" is dedicated to move a chosen percentage of consumption which is over the optimal subscription to the consumption which under the optimal subscription for each user, which will from now on be called underconsumption. From Section 2.3.2 this is called load shifting. The reason this thesis are choosing load shifting is that 1/3 of the consumers in a survey were willing to move their consumption from day to night (28). It will also be much simpler to compare the energy tariff cost with the subscription tariff cost before and after moving the consumption. The difference between before and after movement of consumption will also be easier to compare when the consumption is only moved not reduced.

As seen in the flowchart from Figure 4.3, the user of the function first decides the time interval for limiting moving of the consumption, it is originally set to 24 hours. If the user decides the original time interval for moving the consumption, the time interval goes from 12 hours before hour *i* to 12 hours after hour *i*. A problem arises if the hour of the year is either below hour 13 or above 8748, this means that the function will check for hours which is not in the scope of the time period - above 8760 or below 0. The function uses a simplified solution to solve the problem with hours that will check hours beyond the scope, which is if the hour *i* is below hour of the year 13, the function checks 24 hours after hour *i*, and the available hours before hour *i* to 0. If the hour *i* is above the hour of the year 8748, the function checks 24 hours before hour *i* and, the available hours after hour *i* to 8760. To make this available the function, as seen in Figure 4.3, first checks if hour *i* subtracted by 12 is below zero or if hour *i* added by 12 is above 8760.

The percentage of the overconsumption can also be chosen by the consumer, the percentage of the overconsumption is originally set to 100%. Because of the limited time interval of moving consumption, some of the overconsumption might not be moved to underconsumption. Some of the overconsumption might not be moved due to the fact that there is no available underconsuption in the time interval of moving the overconsumption.

The function start at the first consumer in the data set, it then goes through every hour of the time period for that consumer. For the first hour it checks, is there a overconsumption in hour *i* for consumer *k*? If there is not a overconsumption, the function starts checks if there is overconsumption for hour *i+1*. If there is overconsumption for hour *i*. The function sets a temp variable called "P_Moved" which is equal to the overconsumption times the moved percentage in hour *i*.

When "P_Moved" is set, the function controls if the hour *i* is within the time interval where the function can go below or above hour *i*. If the function is between that time period, the function then starts a for loop which goes from 1 to the set time interval for moving consumption. The function then checks if j is odd or even, if j is odd, the function will go forward and if j is even the function will go backwards. The reason for choosing the function to go every other forward and backward is that if the consumer wants to

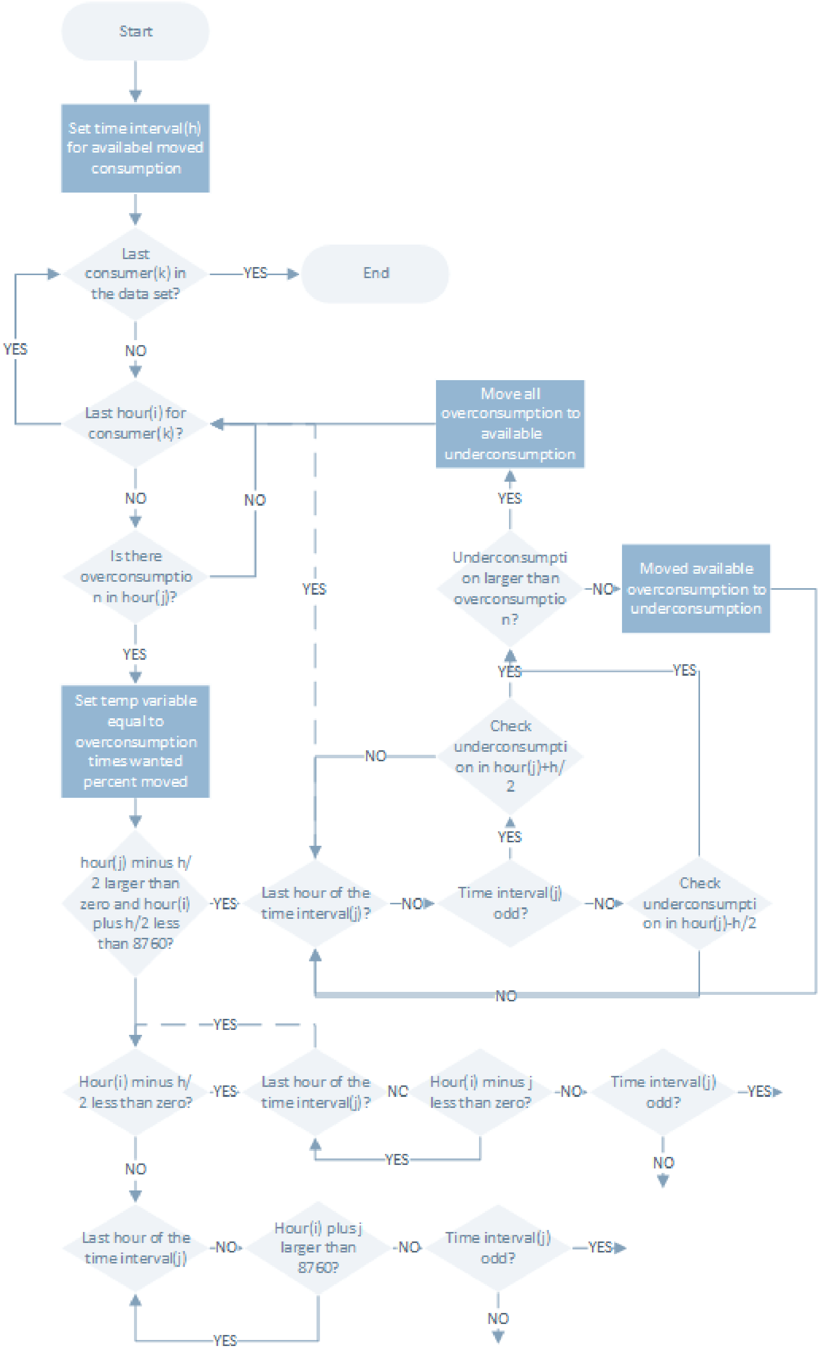

Figure 4.3: The flowchart for the MATLAB function "MovedCons.m".

move their overconsumption, they would do it in the closest hours to the overconsumption.

The function starts at j = 1, therby j is odd and the function will check the hour which is after *i*, *i+1*. The function then checks if there is an underconsumption in hour *i+1*, and if "P_Moved" is not equal to zero. If there is not underconsumption in hour *i+1*, the function goes back to the time interval as seen in Figure 4.3. The function now checks the hour before hour *i*, hour *i-1*. The function then checks if there is an underconsumption in hour *i-1*, and if "P_Moved" is not equal to zero. If there is not underconsumption in hour *i-1*, the function starts at the time interval again and in hour *i+2*. If there is underconsumption in hour *i-1*, the function creates a new variable called "P_Left", which is the total underconsumption in hour *i-1*.

When "P_Left" is set, the function then investigates if the "P_Moved" is larger than "P_Left". If "P_Moved" is less or equal to "P_Left", the function moves all overconsumption in hour *i* to the available underconsumption in hour *i-1*, and starts to the next hour in the data set, hour *i+1*, and then checks if there is an overconsumption in that hour, as seen in Figure 4.3.

If "P_Moved" is larger than "P_Left", "P_Moved" is changed from its original value to the original value subtracted the value of "P_Left", which is $P_Moved = P_Moved - P_Left$. The function then moves all the available overconsumption to the underconsumption till the consumption at hour *i-1* is at the consumer's optimal subscription. The function then starts at the next step of the time interval for hour *i*, and continues to do this until either there is no overconsumption left in hour *i* or the function is at its end in the time interval, which means that the function could not move all overconsumption at hour *i*.

If hour *i* is below 13, with the original time interval, the function will behave as written above. If hour *i* is below 13 will the function will have another statement. The statement is that if hour *i-j*, is below zero, the function will not move the overconsumption to these hours.

The same is done if hour *i* is higher than 8748, with the original time interval. The only difference is that the statement is if hour *i+1* is above 8760, the function will not move the overconsumption to these hours.

The flowchart in Figure 4.3, is not complete, but since the three scenarios behave the same but the only difference is an added if statement, as described above. Thereby it is decided to not have all if-statements after the if-statements, if hour *i-1* is below zero and if hour *i+1* is above 8760, to simplify the flowchart.

4.4 The EMPS model

To take out dataset from the EMPS model, the program "Kurvetegn" is used.

4.4.1 "Samoverskudd.xlsx"

Statnett has its program called "Samoverskudd.xlsx", which can determine the difference between two scenarios for the EMPS model. "Samoverskudd.xlsx" uses data that have been determined by the EMPS model and finds the relevant data for the 34 subareas such as: Production [GWh], Consumer [GWh], Grid losses [GWh], Average losses [GWh], Producer surplus [Mill. Euro], Consumer surplus [Mill. Euro], capacity income [Mill. Euro], loss cost [Mill. Euro], average loss cost [Mill. Euro] and Reservoir change [Mill. Euro]. These data can determine the socio-economic surplus for each subarea and by that the whole model.

Chapter 5

Choosing the Ideal Subscription Fee and the corresponding Excess Demand Fee

This chapter describes the ideal subscription fee and the responding ideal excess fee. First, a short explanation on what should be taken into consideration when choosing the ideal subscription fee, then two alternatives are presented with different results, from these results the ideal subscription fee is chosen.

5.1 Choosing the Ideal Subscription Fee

It is essential to choose an ideal SF to get an ideal EDF. From the hearing document presented by NVE, a new regulation is suggested in Regulations concerning the control of network operations (1). The regulation § 14-2, says that the EDF has to be within a reasonable limit (1). The consumers also have to understand that when using consumption above their subscription is expensive; therefore the EDF should not be too low either.

5.1.1 Choosing Two Alternatives

To choose the two alternatives which this thesis are going to investigate. It is important to get two alternatives that will give a satisfying answer and will give a difference between the two as well. The two first alternatives that were chosen were SF equal to 60 and 90. The reason for not investigating 90 was that EDF was equal to 0.25, which was decided that was too low. Since the EDF for SF equal to 60 was around 1, it was decided to have a higher EDF, and thereby were SF equal to 40 chosen.

5.1.2 Investigation Points for the Ideal Subscription

This thesis will investigate two alternatives where the SF is either 40 or 60 [NOK/kW/-month], the investigation will go through these points:

- The impact of the size of the random sample.
- The difference in cost of each part in the subscription tariff.
- The difference in cost between the energy tariff and the subscription tariff for the two alternatives.
- Analyzing two consumers with different consumption profile.
- An increase in consumption for all consumers.

When the investigation has gone through these points, this thesis will conclude with an ideal SF, which will be used in the in further in this thesis.

5.1.3 The Size of the Random Sample

The size of the random sample can impact the size of the EDF, as described in Section 4.1, this thesis will investigate if the size of the random sample how much will the impact be for the two alternatives of the SF. Choosing the correct size of the random sample that yields the ideal excess demand cost for all consumers is essential such that their subscription tariff is as low as possible. Since the DSOs are regulated to have equal grid tariff income as before, the relationship between the SF and the EDF is based on that the lower the SF, the higher the EDF. The higher the EDF, the more dependent the function are on which consumers are in the random sample.

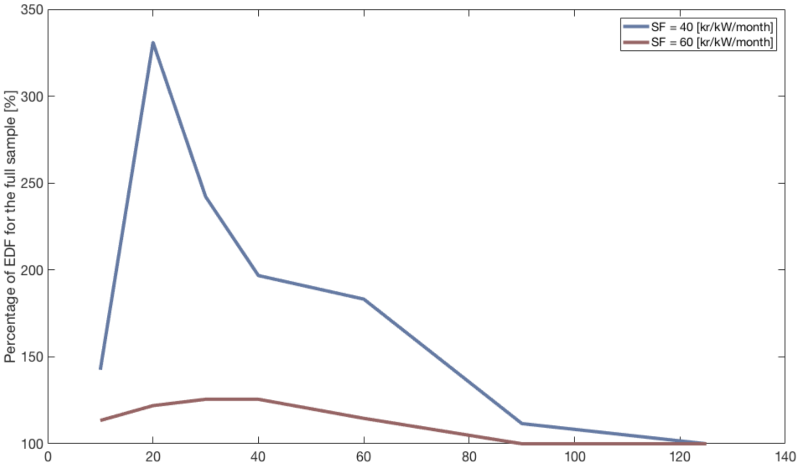

Figure 5.1: The difference in EDF when there are different sizes in the random sample.

When investigating the different sizes of the random sample, shown in Figure 5.1, the EDF is much more dependent on the random sample when the SF is 40 [NOK/kW/month] than when the SF is 60 [NOK/kW/month]. The Figure 5.1, shows that if the random sample is below around 80, the difference between the EDF for the random sample and the full sample when is 40 [NOK/kW/month] are too large. The difference between the EDF for the random sample and the full sample for SF equal to 60 [NOK/kW/month], is smaller and the largest difference is at around 20%. The two alternatives have a noticeable difference when it comes to the dependence of the size of the random sample. Because of the substantial difference in EDF, this thesis will use numbers from the full sample. The EDF for the two alternatives with the full sample is shown in Table 5.1.

Table 5.1: The excess demand fee when the subscription cost is equal to 40 and 60

	Cost	Unit
$C_{ex,40}$	15.85	[NOK/kWh/h]
$C_{ex,60}$	0.82	[NOK/kWh/h]

5.1.4 The Ideal Subscription for Each Consumer

The ideal subscription for each consumer with the two alternatives in SF can be determined.

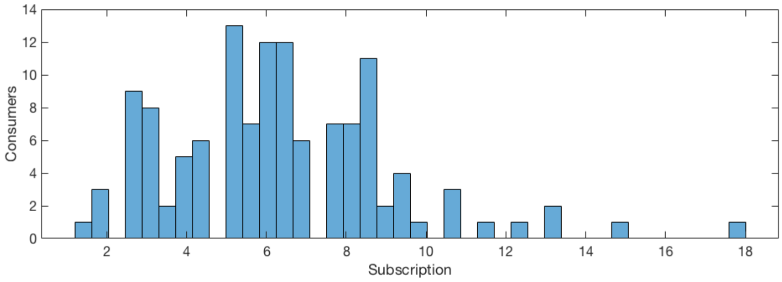

Figure 5.2: The number of consumers on each subscription when SF is equal to 40.

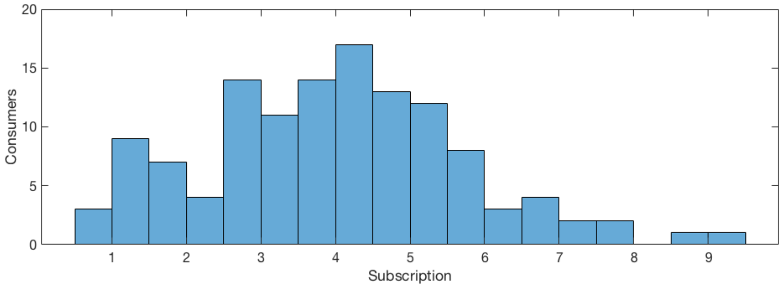

Figure 5.3: The number of consumers on each subscription when SF is equal to 60.

Comparing the Figures 5.2 and 5.3, when SF is equal to 40, the subscription is more spread than when SF is equal to 60.

5.1.5 The Difference in Total Cost

The difference between each part of the total cost for the whole sample has been analyzed. It is reasonable to think that when the SF is smaller, it will take a smaller piece of the cake. For the Pie Chart for each alternative, shown in Figure 5.4, the parts represent the different costs explained in Section 2.6.

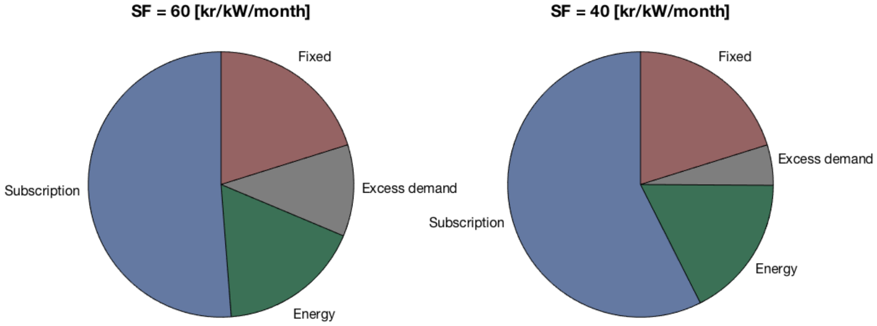

Figure 5.4: The difference in total cost for the two alternatives, SF equal to 60 [kr/kW/Month] and 40 [kr/kW/Month].

The Figure 5.4, shows that the assumption above was wrong. When the SF is equal to 40, the subscription part has a more significant percentage of the total cost than when the SF is equal to 60. The reason why the subscription part is larger for SF equal to 40 than for SF equal to 60 is that the consumers want to minimize their cost. With a low SF and a high EDF, it will be more beneficial to subscribe to a higher power than to have more consumption which is over the subscription. An explanation for why the consumers choose a higher subscription when the SF is low is that for every excess demand [kWh/h], the consumers have to pay a fee of 15.85 [NOK/kWh/h], as shown in Table 5.1. As explained in Section 4.1, the optimal subscription has a step of 0.5 [kW], when comparing for the whole time period, which is one year, the cost of increasing the subscription is 240 [NOK/kW/year].

The interaction between these two makes the consumers want to have as little excess demand as possible. The interaction between the ideal subscription and the excess demand is different when the SF is 60 [NOK/kW/month]. The cost of increasing the subscription with 0.5 [kW] will cost 360 [NOK/kW/year], while the EDF, as shown in Table 5.1, is

0.82 [NOK/kWh/h]. When the SF is 60 [NOK/kW/month], the consumers will choose a small subscription, since the interaction between the SF and the EDF makes it beneficial to have a large amount of excess demand. While when the SF is 40 [NOK/kW/month], the consumers will choose a large subscription, since it is beneficial for the consumers to have a small amount of excess demand.

5.1.6 The Difference in Cost for all Consumers

What happens with the cost for each consumer when comparing the two alternatives for the SF, 40 and 60 [NOK/kW/month], with the energy tariff?

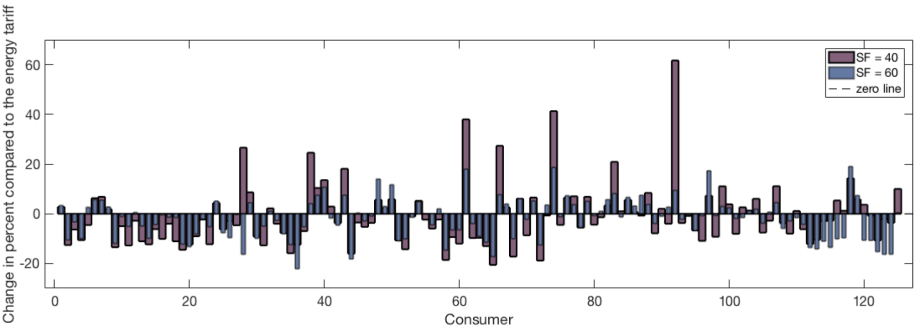

Figure 5.5: The change in percentage from the energy tariff to the subscription tariff for the two alternative when SF is equal to 40 and 60 for each consumer.

The Figure 5.5 shows that when SF is equal to 40 [NOK/kW/month], the change in percentage from the energy tariff to the subscription tariff for each consumer varies more than when SF is equal to 60 [NOK/kW/month]. The reason why SF equal to 40 is varying more, is that the consumers are more dependent on the interaction between their excess demand and their ideal subscription when the EDF is large. An increase in grid tariff is problematic because the consumers will complain if the grid tariff cost is too large, which explained further in Section 2.6.3.

Looking further into one of the consumers with the highest increase in cost for both alternatives, consumer 61. Consumer 61 has a peak power of 17.73 [kWh/h] for the time period. The consumption profile for consumer 61, shown in Figure 5.6, shows that the consumption has a high variation from hour to hour. The subscription when the SF is equal to 40 is 15 [kW], and the total overconsumption for consumer 61 is 31.37 [kWh/h]. With a high subscription and a small overconsumption mean that the difference between the consumption above subscription and the subscription are, the overconsumption, as shown in Figure 5.6, are easily moved.

When the SF is 60, the subscription for consumer 61 are 5 [kW], and the total overconsumption is 3118.88 [kWh/h], which shows that the difference between the overconsumption for the two alternatives, 40 and 60, are large for a single consumer. By having the SF equal to 60, consumer 60 will have a significant portion of excess demand to move, which can give a larger overall reduction in the maximum grid peak.

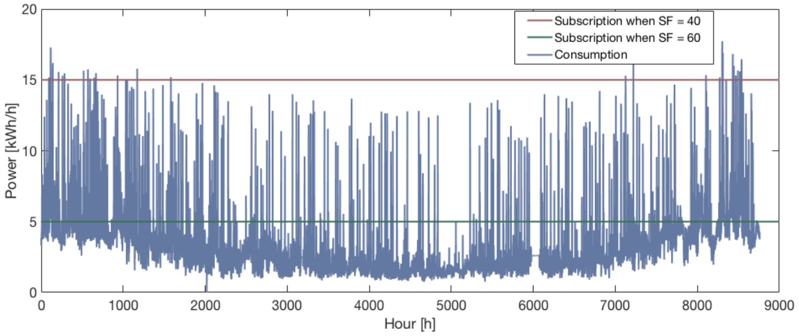

Figure 5.6: The consumption for consumer 61, with the ideal subscriptions for the two alternatives SF = 40 and SF = 60.

The total cost for each alternative, shown in Figure 5.7, shows that when the SF is equal to 40, the subscription cost takes almost 3/4 of the total cost, while the excess demand cost is small. When the subscription fee is equal to 60, the subscription cost has a smaller part than for the total cost for the same alternative for all consumers, as shown in Figure 5.4.

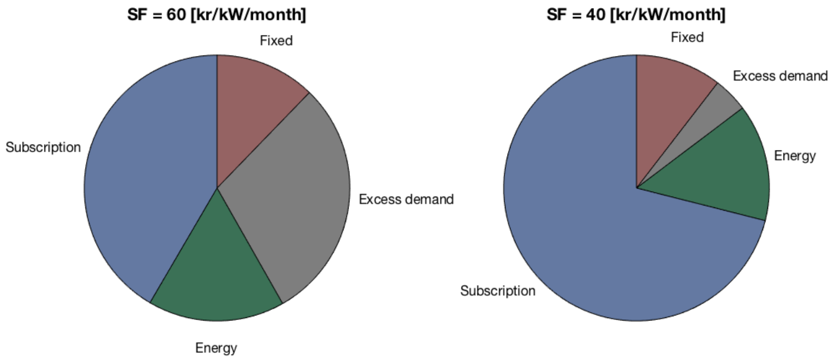

Figure 5.7: The different sectors in total cost for consumer 61, with the two alternatives; SF = 40 and SF = 60.

5.1.7 Change in Consumption

The consumption profile of each consumer is unique, and when the DSOs are analyzing the ideal subscription for each consumer in their grid, the DSOs has to take into account historical data and will try to give the consumers the ideal subscription, such that the consumers can minimize their cost. As described in Section 2.2.2, the Norwegian household is dependent on the outdoor temperature, what happens if the year is colder than the anticipated? The original load dataset, described in Section 3.1, is modified, all 125 consumers have increased their consumption between hour 1 to 300, and hour 5000 to 8760 with 20 percent. The ideal subscription for all consumers is the same as found in Section 5.1.4.

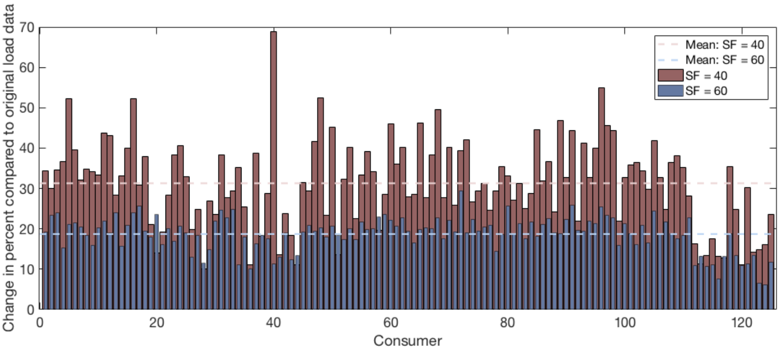

Figure 5.8: The change in percentage from the original load data to the modified data set, for each consumer for the alternatives SF = 40 and SF = 60 when increasing the consumption by 20%

The change in percentage from the original load data to the modified data set, in cost with the same subscriptions are shown in Figure 5.8. The Figure 5.8, shows that when the SF is 40, the mean increase in cost is 31.28%, while when the SF is 60, the mean increase is 18.73%. Looking further into the difference between the two alternatives when the consumption is increased, almost all consumers have a larger increase with the SF equal to 40 than when it is equal to 60. One consumer has an increase of nearly 70% for SF equal to 40, and most of the other consumers are within 20% to 50% increase in cost increase. When the SF is equal to 60, the consumers do not have the same variation as to when SF is equal to 40. Almost all consumers lay within 15% to 25% increase in cost.

An important note to take into account is that the 20% in increase in consumption from hour 1 to 3000 and 5000 to 8760, does not give an absolute answer to which of the SF that is best.

Since the subscription when the SF is 40 is high, the consumers do have more room to fill if their consumption increases, thereby larger underconsumption. With larger underconsumption, the consumers can increase their consumption at hours where there is available underconsumption. The consumers will have a larger potential of increasing their consumption when SF is equal to 40 then if SF is equal to 60.

5.1.8 Choosing the Ideal Subscription Fee

To choose the ideal SF which will be used in further chapters, the points made in Section 5.1, will be used. When the SF is equal to 60, the impact of the size of the random sample is smaller than when the SF is equal to 40. Even though the underconsumption over a year is larger when SF is equal to 40, the cost of having a overconsumption, which is 15.85 [NOK/kWh/h], is too high. The DSOs wants a reliable grid tariff that can be predicted over the years, such that the DSOs does not have to change the cost depending on the usage. Section 5.1.7, shows that with a SF equal to 40, the EDF is too high, making the total cost unpredictable for a year. While when the SF is equal to 60, the cost is much more dependent. The ideal SF chosen for further work are 60 [NOK/kW/month].

Table 5.2: The subscription tariff variables which is used further in this thesis.

	Cost	Unit
C_{en_S}	0.05	[NOK/kWh]
C_{fixed_S}	1060	[NOK/year]
$C_{Subscription}$	60	[NOK/kW/month]
C_{ex}	0.82	[NOK/kWh/h]

Chapter 6

Moving the Consumption from Overconsumption to Underconsumption

This chapter presents the moving of consumption from overconsumption to underconsumption. An analysis is conducted to see how the consumers and the total load data are responding both in demand and economic perspective. The reduction in peak load from the load data is then implemented into the firm power profile and analyzed to see the whole economic perspective.

6.1 The Change in Consumption at the Peak Hour for the Total Load

The consumption for each consumer has been moved as explained in Section 4.3.

The Figure 6.1 shows two scenarios, "before" and "after". The before-scenario is the scenario where the consumers have their original consumption, and the after-scenario is the scenario where the consumers have moved their consumption according to Section 4.3. An interesting observation is that it would be expected that every consumer will have a decrease in consumption, from before to after, for the peak hour of the total load, this is not the case. As seen in Figure 6.1, for some of the consumers their consumption is increasing from before to after. The reason for the increase in consumption can be explained by the subscription and the consumption for these consumers. The consumption in the before-scenario are lower than the subscription for these consumers, and at hours around the peak hour for these consumers are high. The reason for this is that the consumers have moved their consumption into the peak hour, which means that their consumption at this hour is increasing. Even though some of the consumers have an increase in consumption, most of the consumers have a decrease in consumption. Thereby the average consumption is

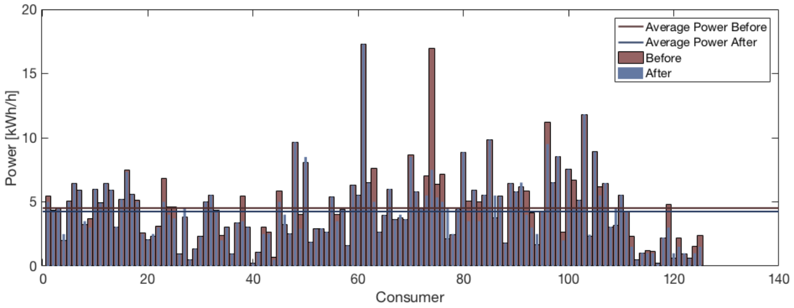

Figure 6.1: Consumption for each consumer in the peak hour for when the consumption is at its original point or when the consumption has been moved, which is called before and after, respectively.

decreasing from the before-scenario to the after-scenario, as shown in Figure 6.1.

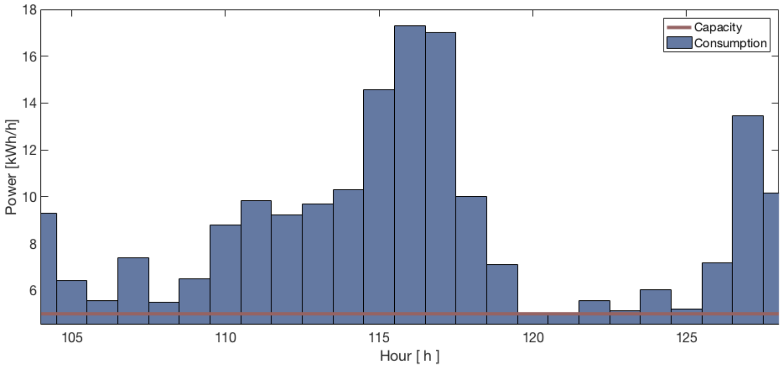

Figure 6.2: Consumption and subscription for consumer 61, +/-12 hours around hour 116.

The average consumption should decrease as most of the consumers are reducing their consumption. As seen in Figure 6.1, the consumer 61 has not changed the consumption at the peak hour. From Figure 6.2, the consumption is always above the capacity within the time interval of +- 12 hours of peak hour, hour 116. Therefore the consumption cannot be moved at the peak hour. The same problem arises for the other consumers with a high peak power in the peak hour, which again means that the average could be lower, but the restriction on how long the consumer can move their consumption is limiting the reduction in peak power for the total load.

6.2 The Duration Curve

A duration curve shows how the consumption for the total load behaves from the highest load to the lowest load. The duration curve will be based on the time period, explained in Section 3.1, and will have all hours in that time period.

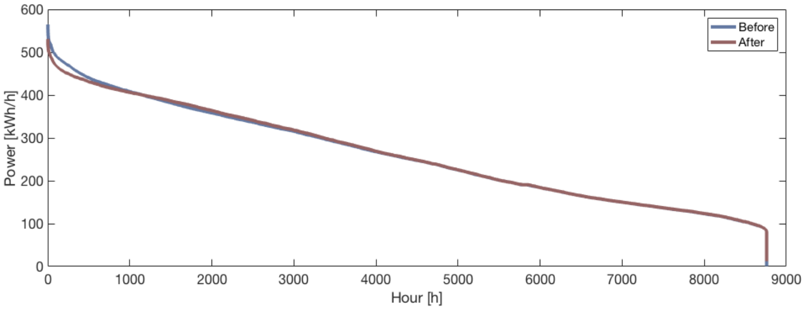

Figure 6.3: The duration curve for both scenarios, the original consumption and when the consumption has been moved, before and after, respectively.

The duration curve, shown in Figure 6.3, displays that there is a reduction in peak power. Figure 6.3 also displays that there is a reduction in power until around hour 1000, and after hour 1000, there is an increase. It makes sense that there is decrease first and then an increase since the consumption is only moved from excess demand to hours where consumption is under subscription. Because of the restriction in the time interval, these hours are around the high load, which means that other consumers might have a high load there. With the total sum of consumption for the time period is the same for both scenarios. If there is a reduction in peak power, there must be an increase in other hours; this is shown in Figure 6.3. The peak load is decreased from 564.58 [kWh/h] to 530.87 [kWh/h], which yields a reduction of 6.35% under the assumption that the consumers only can move within the time interval explained in Section 4.3.

6.3 Economical change when moving the overconsumption

The DSOs has their revenue regulated as explained in Section 2.6. What happens with the revenue if the consumers are moving their consumption from overconsumption to underconsumption.

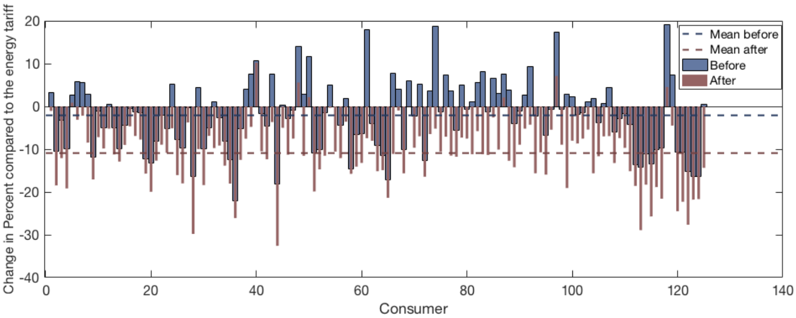

Figure 6.4: The difference in percentage from the energy tariff to the subscription tariff with the two scenarios, where the consumption is at its original and were the consumption is moved.

The Figure 6.4 shows the change in percentage from the energy tariff to the subscription tariff for the two scenarios. The before-scenario is the scenario where the consumption is at is the original profile. The after-scenario is the scenario where the consumption has been moved according to Section 4.3. The average change in percentage when the consumption is moved is -10.92%, as seen in Figure 6.4. Most of the consumers will have a reduction in their grid tariff cost, but when looking at consumer 40, the reduction is small compared to the other consumers.

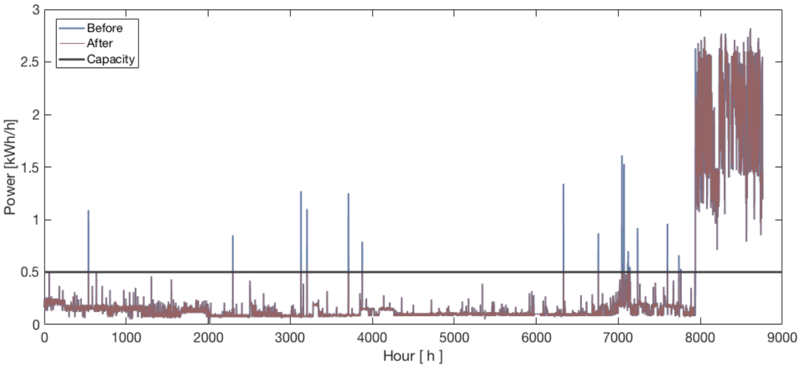

Figure 6.5: Consumption before and after the consumption is moved, and subscription for consumer 40

The consumption behaviour for consumer 40, as shown in Figure 6.5, is not a typical behaviour for a household, for most of the year the consumption is between 0 and 0.5 [kWh/h], with a few peaks, where the highest peak is at around 1.5 [kWh/h]. At the end of the year though, the consumption increases to around 1.5 to 3 [kWh/h], which is interesting as the capacity is already set for 0.5 [kW], which is the lowest possible subscription. Since consumer 40 a low consumption, the change in percentage is around 10% the change in cost is not that much, since the cost of the energy tariff is 2239.8 [NOK].

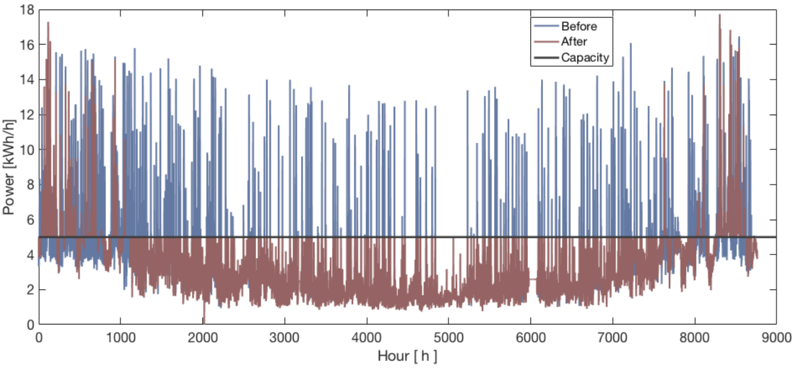

Figure 6.6: Consumption before and after the consumption is moved, and subscription for consumer 61

One of the consumers with the highest reduction in grid tariff cost when moving the overconsumption is consumer 61, as shown in Figure 6.4. The consumption for consumer 61, as shown in Figure 6.6, shows that the consumption has a lot of high peaks throughout the year and most of the power can be changed from overconsumption to underconsumption. The consumer has a consumption behaviour that has a high variation, as shown in Figure 6.6, this means that the overconsumption can easily be moved to underconsumption. There is though a problem with hours where the overconsumption cannot be moved, these hours might be a problem when trying to reduce the total peak power. Another interesting point is that the power capacity is only at 5[kW], while the highest peak is at 17.73 [kWh/h]. The consumer has a lot of high peaks, which can be reduced by moving the overconsumption, which again can explain the high reduction in grid tariff. The change in grid tariff cost from energy tariff cost to subscription tariff cost with moved consumption for consumer 61 is -7.43%. For consumer 61, the difference between the cost from the original scenario to the moved scenario for the subscription tariff is -21.50%.

6.4 Trying to move all Overconsumption

What happens if the consumers can move all the overconsumption into underconsumption, e.g. there is no overconsumption left. To make this happen the time interval of the MATLAB function "MovedCons.m" is set to 4000, this is to be sure that there is no overconsumption left.

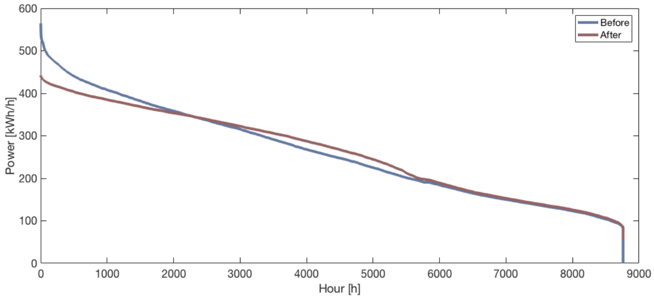

Figure 6.7: The duration curve for both scenarios, the original consumption and when the all the overconsumption has been moved, before and after, respectively.

The difference between Figure 6.3 and Figure 6.7 is remarkable. When all the overconsumption is moved, the peak hour is reduced to 446.30 [kWh/h] and is a reduction of 20.95%. This comes with a cost though, Figure 6.6 shows that most of the high consumption comes on days after each other and from Section 2.2.2, most of the energy use in Norwegian household is used for heating and some of the days might be cold, which explains why the consumption is that high. With the consumption that high, this is also a problem when the time interval is at 4000, which means that the consumption that can not be changed in the winter might be moved to the summer period. Moving the consumption from winter to summer is not a reasonable solution as power demand is something the consumers need now and not in two weeks.

The interesting point in moving all overconsumption for the consumers is to see the possibility of the consumers having a flat consumption throughout the year. It is not a reasonable assumption that the consumers can wait two weeks on using the washing machine since it is cold. Though, it might be interesting if the consumer gets a battery, this is not the only factor that the consumer thinks about when using power. Other factors are temperature, the energy price, etc. All these factors have to be taken into consideration when the consumer decides if they want to reduce power.

6.5 The EMPS model

6.5.1 Changing Firm Power Profile

As explained in Section 2.7, the demand in the EMPS model is divided into two subgroups, industry and general supply, this thesis will focus on changing the consumption profile in residential housing, thereby general supply. There are different methods to change the consumption profile, but since one of the objectives of this thesis is to move the consumption from overconsumption to underconsumption, there should not be a reduction in consumption throughout the year. A method to only change the consumption profile without large losses is to change the firm power profile in the EMPS model, which is explained more in depth in Section 2.7.1. By flatting out the profile, it becomes easier to compare the difference from the original scenario, since the consumption each week is still same.

The firm power profile can be more flatten out by changing the variables for each hour for each week:

$$P_{ref_{new},i} = X * \bar{P}_{ref} + (1 - X) * P_{ref_{old},i} \tag{6.1}$$

The purpose of Equation 6.1 is only to move the consumption and still make it have the same average, $\bar{P}_{ref}$. By using Equation 6.1, the old reference consumption for hour i,$P_{ref_{old},i}$, can be flatten out by a variable, X, this variable has to be from 0 to 1, depending on how large the change is wanted to be. If X is equal to 0, the new reference consumption for hour i, $P_{ref_{new},i}$, will be equal to the old reference consumption for hour i. While if X is equal to 1, the new reference consumption will be equal to the average consumption for week j, $\bar{P}_{ref}$. It's important to note that for every hour in that week, the variable, X, has to be the same, if not, the average consumption for week j will change.

By using Equation 6.1, the firm power profile can now be flatten out. From Chapter 6, the load aggregation for the 125 residential houses has a reduction in the peak power from the original scenario with 6.35% when moving as much overconsumption to underconsumption as possible inside the time limit of 24 hours. This thesis wants to see whats happening if the general supply does the same.

To achieve 6.35% reduction in the average of the highest tops of every week in the firm power profile, the variable, X, in Equation 6.1 has to be around 35%, to be sure that the reduction is enough, the variable, X, is chosen to be 40%. The new firm power profile with the change is then implemented into the EMPS model. Which is defined as the new scenario, while the original firm power profile implemented into the EMPS model, is defined as the old scenario.

6.5.2 The Difference in General Supply Consumption between New and Old Scenario for Norway

There are two alternatives in looking at what happens with firm power for all the subarea in Norway combined when changing the profile. The first alternative is to look at duration curve with independent hours, where the consumption and responding hours between the two alternatives might be different, but both go from their highest consumption to their lowest. The second alternative is that there is a duration curve for the old scenario, which goes from the highest to lowest consumption and the new scenario has a consumption curve with their respective hours as the old scenario.

6.5.3 No Relationship between the Scenarios

With the first alternative when there is no relationship between the scenarios, the consumption of each alternative, as shown in Figure 6.8, shows that with the original scenario. Figure 6.8 shows that the consumption is higher for the peak, and the interception between a higher and lower consumption happens at around hour 60 000, around 23%. While for the lowest consumption hours, the original scenario has lower consumption in these hours.

Lower consumption for the original scenario during the low consumption period makes sense since the new profile compared to the old profile, is reduced during the hours with high consumption and the hours with low consumption is increased.

By looking at the peak power for each scenario, the original scenario has a power consumption of 20.66 [GWh], while the 40% reduction scenario has a power consumption of 19.43 [GWh]. The reduction from the original scenario to the 40% scenario is around 6%. The reduction is the same as for the 125 residential houses in Chapter 6.

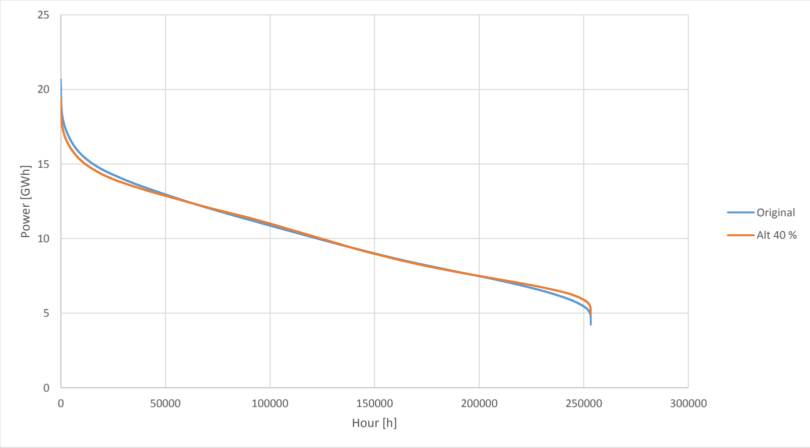

Figure 6.8: The duration curve of firm power for the all subareas in Norway combined with the two scenarios, original and 40% reduction, where the two are independent of each other

Relationship between the Two Scenarios

The filtering is chosen to be at the original scenario, where the consumption, shown in Figure 6.9, is going from highest to lowest for all hours. The 40% reduction scenarios consumption is compared to these respectively hours. The peak hours, shown in Figure 6.9, shows that the original scenario still has the highest hours, but when looking at hour 1500 to 2000, around 0.6%, shown in Figure 6.10, the 40% reduction scenario starts to have higher consumption than the original scenario. The reason why the 40% reduction scenario gets higher peaks, during these hours can be explained in Section 6.5.1. The firm power profile is dividing weekly consumption into hourly. For a week with high consumption, the average hourly consumption will be high. The average hourly consumption is so high that even hours with consumption below the average hourly consumption are within the top 2000 highest consumption hours. The 40% reduction profile will increase these by using Equation 6.1, thereby an increase from the original scenario.

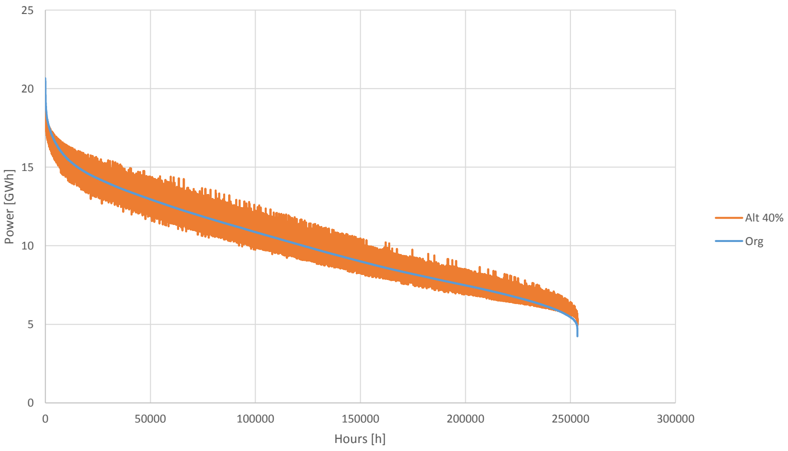

Figure 6.9: The duration curve of firm power for the all subareas in Norway combined with the two scenarios, original and 40% reduction, where the duration curve is the original scenario while the 40% reduction is the responding value to the original scenario.

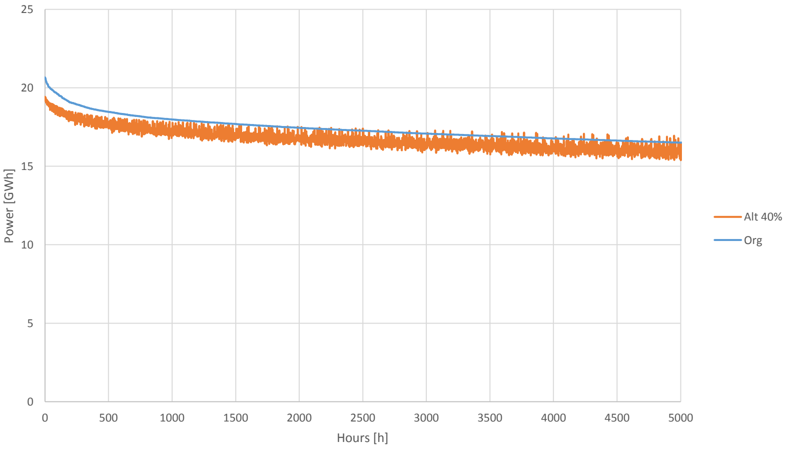

Figure 6.10: The first 5000 hours of the duration curve of firm power for the all subareas in Norway combined with the two scenarios, original and 40% reduction, where the duration curve is the original scenario while the 40% reduction is the responding value to the original scenario.

6.5.4 The Price for a Subarea

An interesting factor is what is happening with the prices for a subarea, even though this thesis has not taken into account that the consumers depend on the power price when moving their consumption, as explained in Section 4.3. The prices will change if the consumption in peak load hours is reduced. Though other factors come into play, the industry, as explained in Section 2.7, are much more price dependent, which will again affect the power price.

The Price for subarea NORGEØST

The difference between the price and firm power is that firm power can be aggregated. While the price is different for each area and either be checked for each area or take an average of the all the subareas in Norway, the latter will not show the price as good as the former. Therefore will this thesis only focus on one subarea. In this Section, the thesis will focus on the price for area NORGEØST.

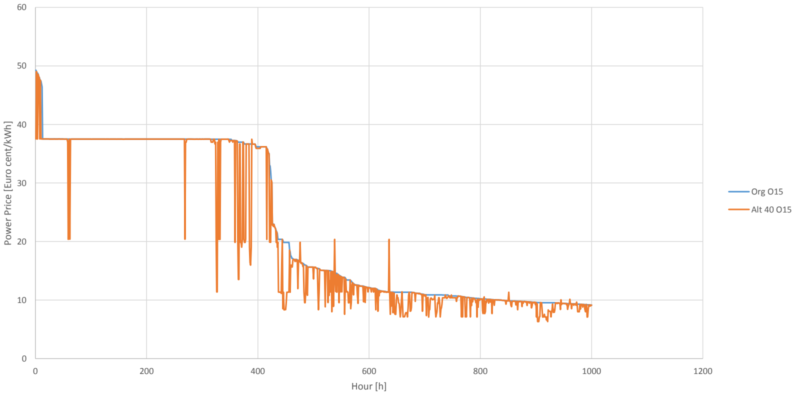

Figure 6.11: The first 1000 hours of the duration curve of the price for the subarea 15 with the two scenarios, original and 40% reduction, where the duration curve is the original scenario while the 40% reduction is the responding value to the original scenario.

The Figure 6.11, filtered by having the highest to the lowest power price for the original scenario, the hours used in Figure 6.11 are the 1000 highest price hours of the total 253 344 hours in subarea 15. An interesting point is that for around hour 10, the price above the rationing price for industry, which means that for those 10 hours there is no industry on, but the price is still as high as almost 50 [Euro cent/kWh]. The reason why it is around 50 [Euro cent/kWh], is that at 50 [Euro cent/kWh], the firm power demand starts its rationing. The Figure 6.11, shows that the new scenario, 40% reduction, has fewer hours at the firm demand rationing price, 50 [Euro cent/kWh]. The two scenarios price has the same movement, but as expected the price for the 40% reduction scenario becomes smaller at some of the rationing prices. The 40% reduction scenario has is also usually smaller after the rationing price, but some hours it is larger.

6.5.5 The Socio-Economic Surplus

As described in Section 2.5, the Norwegian government wants to increase the social welfare as high as possible, this means that when changing the firm power profile, there should be an increase in social welfare from the economic perspective. By using the model

"Samoverskudd.xlsx", explained in Section 4.4.1, this thesis can determine the difference between the socio-economic surplus for each scenario.

The Difference between the Original Scenario and the 40% Reduction Scenario

The most interesting part is what happens with the socio-economic surplus when the consumers try to reduce their peaks, how much will it affect the system. Producer surplus in Norway is reduced with 11.2 [Mill. Euro], it is possible to think that its because the production has been reduced, but the production has increased by 21.5 [GWh], this means that the producers in Norway are producing more and are getting less income. The producers in Sweden, Denmark and the Rest are also having a reduction in income, while in Finland there is an increase. Sweden has a production increase of almost 50 [GWh]. The Consumer surplus in Norway are as expected increased, but with only 8.32 [Mill. Euro], while Sweden has an increase of 7.32 [Mill. Euro], the consumers also have an increased consumption in Norway by 1.67 [GWh], and for the rest of the countries, it is increased in Sweden, Finland and the rest, while for Denmark it is decreased. When taking into account the Capacity income, loss cost and reservoir change, the socio-economic surplus between the two scenarios, as shown in Table 6.1, in total is increased by 3.15 [Mill. Euro].

Table 6.1: The Socio economic surplus for each Area in the EMPS model, when changing the firm power profile from original to a 40% reduction.

Area	Socio Economic Surplus [Mill. Euro]
Norway	-1.95
Sweden	2.55
Finland	-0.20
Denmark	1.07
Rest	1.67
Total	3.15

An interesting point is that the consumer surplus is increasing in Sweden, this is because Sweden is coupled to Norway, and Swedish consumers are benefiting that Norwegian consumers are changing their consumption profile. There will be more available load for the Swedish consumers if the Norwegian consumers are changing their load.

6.5.6 Economic Change for Consumer 61

With the power prices for each scenario, how much will consumer 61 decrease its cost when inserting the power consumption for each alternative. Consumer 61 is one of the consumers with the largest change in consumption when moving the overconsumption to underconsumption. Consumer 61 has also been analyzed in Section 6.1. Some important notes is that, as explained in Section 3.1, the load data are from 2017, and as explained in Section 2.1, consumers have different behaviors depending on different factors, especially temperature. It is also important to precise that the Matlab function "Flytteforbruk.m" does not considers the power price when moving the overconsumption.

Therefore the purpose of this chapter is only to see if consumer 61 gets a decrease in power cost which is reasonable, the result can therefore not be taken literally.

As explained in Section 2.7, the EMPS operates on a weekly basis, while the load data, is on a date basis. The load data has been changed from date basis to weekly basis, where it starts at 02.01.17, which is the first day in the first week and ends at 31.12.17, which is the last day in the 52. Week. With these data, consumer 61 has 8736 hours, which is the same as the EMPS model. The price data used in this comparison is from subarea 15 (NORDØST), for the whole time period.

The load data for each scenario is then combined with the price data for each scenario for the EMPS model. Since the load data is only over one year, a simplification has been made such that consumer 61 is assumed to have the same consumption profile for every year for 30 years, such that the comparison can be made.

To achieve the difference in price the original load profile is being multiplied with the original scenario price in the EMPS model, while for the moved consumption profile is being multiplied with the 40% reduction scenario.

When looking at the percentage change in cost for the total 30 years, the difference is only approximately 0.5%, while it is important to note that this only the power price. A reduction of 0.5% for consumer 61 for 30 years is not what the consumer expected when they moved all the consumption from overconsumption to underconsumption. Consumer 61 has also one of the largest reduction in subscription grid tariff, shown in Figure 6.4, which means that the difference might be even smaller for other consumers.

Another interesting part is to look at Consumer 61, if the consumer decides not to move their consumption, e.g. all other consumers are moving their consumption and the power price changes. Looking at the two alternatives where consumer 61 is not moving and moving his consumption. By comparing the total cost of power with the consumption profile for consumer 61 for both alternatives, the difference in power price for 30 years is only -0.29%, while for the grid tariff the difference is -7.43%. The impact of the change in grid tariff will have a larger impact on the consumer than the power price.

Chapter 7

Discussion

This chapter discusses the process of choosing the Methodology and the analysis.

7.1 The Methodology

The function "FidningIdealExDFee.m" uses a simplification for solving the statement that DSO should have an equal income for both scenarios. The function's statement is to have the absolute difference between the two tariff income should be less than 1%. Here the function can use optimization.

A problem explained in Section 5.1.6, was the difference in grid tariff for each consumer. The function should try to find the ideal excess demand fee where the difference in cost for each consumer is as low as possible as a statement. The difference in cost is important since the consumers are complaining about their grid tariff, as explained in Section 2.6.3.

The time interval for moving the consumption is set to +/- twelve hours. The reason for setting the time interval to +/- twelve hours is that power is something the consumers often need immediately. As explained in Section 2.2.2, the consumption for a household is 57 % temperature, which means that if the consumers decide to take off their indoor heating. The indoor temperature will go down, and after a while, the consumer will have to turn it on the heat, such that the temperature gets to a reasonable level. The same can be said about other electrical applications. If the consumer wants to wash their clothes, they cannot wait a week. Thereby the time interval of +/- twelve hours seems reasonable.

The function "MovedCons.m" uses only load shifting for moving the overconsumption to underconsumption. Will the difference be more if the function also takes into account other consumer flexibilities? If the consumers are turning off their indoor heating to reduce their overconsumption, do they have to turn it on again when there is available underconsumption? Section 2.3.2 explains that the consumers can also have peak clipping, which will reduce their peaks and consumption. The consumers can reduce consumption, and they do not need to have their water heater on at all times. In this thesis, the choice of having load shifting is decided because it is easier to compare the two grid tariffs and the scenario in the EMPS model.

The function "MovedCons.m" only considers the factor that the consumer has a overconsumption in the hour looked at. Another interesting factor is the power price. Will the function be more realistic if the power price is another considered factor for moving the consumption? As described in Section 2.2.3, the consumers are inelastic for price changes. As described in Section 6.5.6, the difference in price is small for a consumer.

7.2 The Ideal Subscription Fee

As Section 5.1.8 describes, the ideal subscription fee for this thesis is 60 [kr/kW/month]. The points made in Section 5.1, has some interesting factors. One of the most important factor is the difference between the energy tariff and the grid tariff for each consumer. As Section 2.6.3 explains, there have been complaints about an increased grid tariff cost when the grid tariff has been changed from energy to power. Complaints are something that the DSOs want to avoid, complaints will come in the newspapers, and people will become more negative to the change of grid tariff. From the two alternatives presented in this thesis, SF equal to 40 and SF equal to 60, SF equal to 60 yields the lowest change from energy to subscription tariff, as explained in Section 5.1.6. While it could be interesting to increase the SF, this thesis tried at first to set the SF equal to 90. When SF was equal to 90, the EDF was 0.25 [kWh/h]. While it has been established, from Section 5.1.4, that the higher the SF is, the lower the subscription the consumers are subscribing to. Thereby the available underconsumption for each consumer will be smaller with SF equal to 90. Which means that there is less room for moving the overconsumption, and with an EDF such small, will the consumers consider a moving their overconsumption? How much will the consumers change their consumption profile for if their house is cold and they want to increase the indoor temperature? A SF equal to 90 might get the right result in theory, but in practice it might not work, thereby this thesis chose to pursue the two alternatives, SF equal to 40 and SF equal to 60.

7.2.1 A Higher EDF

While the difference between SF equal to 40 and SF equal to 60, gave a large difference in EDF. When the SF was equal to 40, the EDF was almost 20 times higher than when SF was equal to 60. What will happen if the SF were in between these two alternatives? It is established that a higher EDF will yield a larger variation in grid tariff cost for each consumer.

7.3 The Change for Users

In the hearing document published by NVE in October 2017, the NVE stated that if the consumers are adjusting their consumption without a benefit of the grid can be represented as a socio-economic loss (1). One of this thesis objectives is to look at how the socio-economic surplus is changing when the consumers are moving their consumption to get a more flatten out consumption profile. When all consumers are trying to move their consumption within the given time interval of twelve hours, as explained in Section 6.2, the reduction in peak hour is 6.35%. Looking at Figure 6.1 and explained in Section 4.3, the consumers do not know when the grid is at maximum capacity, they are only trying to move their consumption from overconsumption to underconsumption. Some of the consumers are moving their consumption to the peak hour, as explained in 6, which means they are getting a higher consumption during the peak hour. Other consumers are not moving their consumption from the peak hour, like consumer 61 which has a load of 17.29 [kWh/h] during the peak hour. The consumers are not getting an initiative for moving their consumption when the grid is at its maximum capacity. From a socio-economic perspective these consumers should be able to move their consumption during the peak hour, and by not getting any initiative for moving their consumption, there will be socio-economic losses for the total system.

The thesis tries to see how large the potential is if all 125 consumers are moving their consumption as much as possible for the whole time period, as explained in Section 6.4. By moving all their overconsumption to underconsumption for a time interval of 4000 hours, the reduction in peak hour is 20.95% from the original scenario. The potential of moving the consumption in peak hour is remarkable, but since the consumers are getting no initiative for it, they will have no profit in changing their consumption at that particular hour.

Another way to look at the potential of the reduction in the power grid for every consumer is to add all optimal subscriptions for each consumer together. The total of the optimal subscriptions can get an answer of what the total reduction in maximum load will be. From Figure 5.3, The total of the optimal subscriptions is 467.5. The reduction from the peak hour at the original scenario to the total of the optimal subscription is -17.2%. The reduction is thereby lower than if the time interval is set to 4000. An explanation for the higher reduction with the time interval of 400, is that the some of the consumers do not have an overconsumption at the peak hour, and they do either have a high consumption around that hour either.

As explained in Section 5.1.7, the ideal subscription does not have to be the ideal subscription for the forthcoming year. The consumption in households are dependent on the outdoor temperature and if the there is an unusually cold winter, and the DSOs didn't pick that up from their meteorology analysis. The consumers will most probably have an increase in their consumption for that particular year. By that, the subscription for each consumer will be lower than their ideal subscription for that year. If the subscription is lower for each consumer, it will have two negative factors. The first factor will be that the consumers will complain about their high grid tariff cost. The second factor will be that because of the consumers high grid tariff cost, the DSO will have an increase in income. The income is regulated by NVE and by having a too high income, the DSO will have to pay back the income which is too high. Which again will cause complaints about the DSO trying to make more money than they can.

From Section 4.1, for the DSO the income from the subscription tariff should be equal to the income from the energy tariff. As explained in Section 2.5.1, if the DSOs have a reduction in their income they have to increase their grid tariff cost, and the reduction from today's cost to the cost if all changes their consumption, as shown in Figure 6.4 the difference is -10.92%. Which means that the DSO is getting 10% less than anticipated, and if the DSO are increasing the subscription tariff cost. Then the cost for all consumers will increase, and some of the consumers will have a larger increase in grid tariff. As explained in Section 2.6.3, consumers have already complained about the increased cost in the grid tariff, if a consumer has an increased cost of 30%, are NVE going to say the DSOs overcharged the consumer or are NVE telling the consumer to reduce their consumption? These questions are important to answer before changing the energy tariff to subscription tariff. NVE wants the consumers to understand that the grid has a capacity and by having a high power consumption, the consumers are maxing the grid, but as this thesis has established, the grid is not at max capacity at every hour of the year.

This thesis takes into account that all consumers are moving their consumption, as explained in Section 4.3, this is to see the potential of the consumers moving their consumption. As explained in Section 2.3.3, only 1/3 of the consumers are willing to move their consumption to get a lower grid tariff cost. With fewer consumers willing to move their consumption, the real reduction in consumption for all consumers will be smaller than this thesis has investigated.

Another interesting factor is how do the consumers know that they have an overconsumption? Its possible to get real-time data from the HAN-module in the AMR, but the module is sealed, and if the consumer wants to use the module to see the real-time data, the DSO has to unseal it. While the consumers can get data from their DSO or Elhub in the future, as described in Section 2.1.1, the consumers will only get this information 09.00 on the following day. If the consumer has not unsealed the HAN-module, the consumer cannot know that he has overconsumption until 09.00, and as Section 2.6.3 explains, consumers do not understand what power is nor how much power their house is using. How will the consumers then know much overconsumption they are using? As explained in Section 2.6.3, there have already been angry consumers about the new power grid tariff because they have to pay more than they did with the energy tariff. It should be obvious for the consumers to understand what they are paying for and when they have an overconsumption such that they can reduce their consumption.

The grid is built to withstand a high power consumption, and should the consumer get a high cost because they are using the grid at a point where it is not at its maximum capacity? If a subscription tariff is going to be implemented into the grid, there should be available technology such that the consumers can see what they are using at that particular hour? As explained above, for most consumers, they cannot get that information before 09.00 the next day. The consumers need an initiative to change their consumption when the power grid is at its full capacity. From Section 2.6.4, Bjarghov and Doorman purpose a new tariff, when the grid is at its maximum capacity, the consumers will have to pay an excess demand fee for consumption above their subscription. The new tariff will solve the socio-economic losses of consumers moving their consumption at hours where there is available capacity in the grid. The consumers will keep their consumption profile for normal hours. When the distribution grid or the power grid is at maximum capacity, the cost of having a high demand will make the consumers change their demand, and by that having a more efficient method for making DSOs and TSO not having or postponing the reinvestments in the power grid.

The consumer 40, has an increase of 10% in percent when comparing the subscription tariff with the energy tariff with the original scenario of consumption profile. As explained in Section 6.3, consumer 40 is not having a large decrease in cost when moving the consumption. If comparing consumer 40 with a cottage, the consumption pattern will be hard to change since the owners of the cottage might only be there a couple of weekends in the year, and one or two full weeks. The available hours with consumption are both small and when the owners are coming to their cottage a late Friday afternoon, and the outdoor temperature is -10 [deg. C], are they going to think about the cost of the grid tariff? There have already been complaints about a power grid tariff, where a consumer had a cost of 500 [NOK] for using his cottage for one day.

7.4 The EMPS Model

The analysis of the EMPS model could be more thorough. The duration curve is only done for the whole region in Norway. The reduction in peak load, as explained in Section 6.5.3, is around 6% which is the same as for the residential houses in the load data. The analysis has not checked all subareas in the EMPS model and checked if the reduction is the same. To check all subareas in the EMPS model, could be interesting as different subareas have a different percentage of the general supply.

The method used for comparing the two scenarios, original and 40% reduction, is the program "Samoverskudd.xlsx" while the method for taking out the data is kurvetegn. This method is a simplification for comparing the models.

7.5 The Socio-Economic Surplus

The Socio-Economic surplus is increasing, as seen in Table 6.1. For Norway the socio-economic surplus are increasing, but when looking at only producers and consumers there is losses. There are losses since the producers have a higher decrease than the consumers have increased their surplus. It was not expect that the producers had a higher decrease than the consumers had an increase. What is the cost of changing their consumption from their normal habits to being careful of using to much load. As explained above, there is also a socio-economic loss for moving consumption when the grid is not at its maximum capacity. What is that cost for the whole system? This is something that could change the socio-economic surplus into a loss.
It seems that it is the Swedish consumers that are getting the benefit of Norwegian consumers changing their consumption profile. The Swedish consumers have a increase of 7.32 [Mill. NOK].

Chapter 8

Conclusion and Further Work

This chapter contains the conclusion of this thesis, as well as proposals for future work.

8.1 Conclusion

In this thesis, the analysis of the new grid tariff, the subscription tariff, has been presented. One of the main purposes for using subscription tariff is to delay the investments in the grid, and this thesis analyzes the effects of switching from the energy tariff to subscription tariff for each consumer. It also studies the change in load aggregation for the whole data set, when the consumers are trying to increase their consumption above their subscription to hours where their consumption is below their subscription. A thorough technical background on the grid tariff and the consumption behavior for consumers was presented in Chapter 2.

In Chapter 3, the load data was presented. The chapter included choosing the load data, which were used for the analysis in Chapter 5 and 6 The chapter also presented the numbers for each grid tariff, the decision to choose a subscription fee, and then find the ideal excess demand fee from that.

In Chapter 4, the MATLAB functions used to analyze the load data were presented. A flowchart for each function was shown, and the chapter also included thorough explanations of the building blocks of the functions.

Two of the functions were then used in Chapter 5 to analyze the difference between the two presented alternatives; SF equal to 40, and to 60. By conducting a thorough analysis on which alternative is the most ideal for this thesis, where the difference in cost for each consumer is the most vital, the chapter concludes with *the ideal subscription for this thesis is SF equal to 60*, which is used in further analysis.

Chapter 6 uses the function "MovedCons.m" to move the consumption for all consumers, and the economic change for all consumers and individual consumers are presented. The change in consumption in the peak hour is also presented, where the difference between the original and moved scenario is a 6% reduction, which is used in further analysis. The potential of the all the consumers are also presented, where the reduction is 20%. The Chapter presents the modelling of the reduction in the EMPS model, with the firm power profile, which was altered with 40% to get over 6% reduction. Two scenarios are presented, one where the original EMPS data set is used, and one with the 40% reduction scenario. The difference between the two for the peak load was found to be 6%, while it was shown that 23% of the highest hours are reduced. The price for subarea "NORGEØST" showed that there was little difference between the two scenarios. For the socio-economic surplus, there was an increase from the original to the 40% reduction, but the increase was not in Norway, but the countries around.

The thesis concludes that for the socio-economic perspective, the change from energy tariff to subscription tariff could be useful. Though, this thesis has investigated several factors for changing the grid tariff. As explained in the discussion, there are several negative aspects with changing from energy tariff to subscription tariff. These negative aspects should be taken into consideration if the grid tariff is going to be changed to the subscription tariff.

8.2 Further Work

The functions presented in this thesis could be improved by several means. As discussed in Chapter 7, the statement for finding the ideal excess demand can be improved by having the function using optimizing, which can be implemented into the function. If implementing optimization, finding the ideal excess demand fee should also include another statement in the function "FindingIdealExDFee.m", where the consumers should have as little change in grid tariff cost as possible. All functions can also be simplified, by making them more efficient. This thesis uses only load shifting for moving the overconsumption, and it could be interesting to use other types of consumer flexibility, as explained in Section 2.3.2.

It might be interesting to look at other alternatives for the ideal subscription fee, this thesis only considers two alternatives, as described in Chapter 7, the alternative SF equal to 90, was scrapped, but SF equal to 70 or 50 could also be interesting.

The thesis only analysis the residential houses, it would be interesting to analyze the cottages and apartments as well. In Chapter 7, it is discussed how the subscription tariff behaves for a consumer with low consumption through out the year with a high consumption for a short period. A consumer with low consumption throughout the year should be analyzed further, looking at the subscription tariff for cottages could be interesting as the time period for moving the interval is small.

The function "ConsMoved.m" only considers the subscription tariff when moving the consumption. For a real-life consumer, the power price will also be taken into account. By making the function take into account the power price as well, the function can be much more realistic.

The subscription tariff is static, and is not changing when the grid is at its maximum capacity. As described in Chapter 7, the consumers do not know when the grid is at is maximum capacity, the potential of decreasing their overconsumption is 20.95% at the peak hour. With the consumers knowing when there is maximum capacity, a dynamic subscription tariff could be interesting to investigate it further.

A more thorough analysis of the EMPS model, this thesis has only analyzed the total general supply in the EMPS model, it could be interesting to analyze the whole demand for the whole system. The thesis also only analyzes the price in one subarea, other subareas that are interesting are the subarea 12,"NORGESYD", where there are connections to Denmark, Netherlands, and Germany.

This thesis tries to see the effect for one consumer how he will be affected by the subscription tariff. The analysis done in the EMPS model is insufficient as it is not compared with the temperature. An analysis with a temperature independent consumption could be interesting.

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*

Appendices

Listing 8.1: FindingIdealExDFee: The MATLAB function for Statnett's Model for Temperature Correction

```
if  exist('Power_Enebolig') == 0
    Defining_Variables;
end

Power_Enebolig(isnan(Power_Enebolig))=0;
Dato_Enebolig(isnan(Dato_Enebolig))=0;
KundeNr_Enebolig = zeros(10,2);
Cons = zeros(26,8760);
Date = zeros(26,8760);

%Power_Enebolig2(25,:)=[Power_Enebolig(26,1:find(Power_Enebolig(26,:)~=0,1)) Power_Enebolig(26,Power_Enebolig(26,:)~=0)];

k=1;
for i = 1:length(Power_Enebolig(:,1))
    if nnz(Power_Enebolig(i,:)) < 8750
        Power_Enebolig(i,:) = zeros(1,8761);
    end
    if sum(Power_Enebolig(i,:)) ~= 0
        Cons(k,:) = Power_Enebolig(i,1:8760);
        KundeNr_Enebolig(k,1) = KundeNummer_Enebolig(i,1);
        KundeNr_Enebolig(k,2) = KundeNummer_Enebolig(i,2);
        Date(k,:) = Dato_Enebolig(i,1:8760);
        k = k+1;
    end
end

Cons(25,:)=[Power_Enebolig(26,1:find(Power_Enebolig(26,:)~=0,1)) Power_Enebolig(26,Power_Enebolig(26,:)~=0)];
Date(25,:)=Dato_Enebolig(26,Dato_Enebolig(26,:)~=0);
%Dato_Enebolig2(25,:)=[Dato_Enebolig(26,1:find(Dato_Enebolig(26,:)~=0,1)) Dato_Enebolig(26,Dato_Enebolig(26,:)~=0)];

RandS = 125;
Metering_RandS = KundeNr_Enebolig(1:RandS,1);
Cons_RandS = Cons(1:RandS,:);
Date_RandS = Date(1:RandS,:);


%% Variables

Energy_Fixed           = 1749;  % NOK/year
Energy_Energy          = 0.194; % NOK/kWh
Energy_Tariff          = 0;     % NOK


```

```
Sub_Fixed_P          = 1060;   % NOK/year
Sub_Cap60            = 720;    % NOK/kWh/h/year
Sub_Cap40            = 480;    % NOK/kWh/h/year
Sub_Energy_P         = 0.05;   % NOK/kWh
Sub_Excess60         = 0;      % NOK/kWh
Sub_Excess40         = 0;      % NOK/kWh
Sub_Cost             = 0;      % NOK


%%

for i = 1:RandS
    Energy_Tariff = Energy_Tariff+Energy_Energy*sum(Cons(i,:));
end

Energy_Tariff = Energy_Tariff+Energy_Fixed*RandS;

New_Sub = zeros(20,RandS);
Old_Sub = zeros(20,RandS);
k = 1;
Overconsumption60_Try = zeros(RandS,8760);
Sub_Power60 = zeros(RandS,1);
Sub_Tariff60 = zeros(RandS,1);
Overconsumption60 = zeros(20,8760);
Position60 = 0;

while abs((Energy_Tariff-sum(Sub_Tariff60))/Energy_Tariff*100) > 1
    Sub_Excess60 = Sub_Excess60+0.01;
    New_Sub = zeros(20,RandS);
    Old_Sub = zeros(20,RandS);
    for g = 1:RandS
        Overconsumption60_Try = zeros(20,8760);
        for k = 1:20
            Abo = k/2;
            Test = Cons_RandS(g,i);
            for i = 1:8760
                    if Cons_RandS(g,i) > Abo
                        New_Sub(k,g) = New_Sub(k,g)+Sub_Energy_P*Cons_RandS(g,i)+(Cons_RandS(g,i)-Abo)*Sub_Excess60;
                        Overconsumption60_Try(k,i) = (Cons_RandS(g,i)-Abo);
                    else
                        New_Sub(k,g) = New_Sub(k,g)+Sub_Energy_P*Cons_RandS(g,i);
                    end
            end
            New_Sub(k,g) = New_Sub(k,g)+Sub_Cap60*Abo+Sub_Fixed_P;
        end
        [Sub_Tariff60(g,1), Position60] = min(New_Sub(:,g));
        Sub_Power60(g,1) = Position60/2;
        Overconsumption60(g,:) = Overconsumption60_Try(Position60 ,:);
    end
end


Overconsumption40_Try = zeros(RandS,8760);
Sub_Power40 = zeros(RandS,1);
Sub_Tariff40 = zeros(RandS,1);
```

```
Overconsumption40 = zeros(40,8760);
Position40 = 0;


while abs((Energy_Tariff-sum(Sub_Tariff40))/Energy_Tariff*100) > 1
    Sub_Excess40 = Sub_Excess40+0.01;
    New_Sub = zeros(40,RandS);
    Old_Sub = zeros(40,RandS);
    for g = 1:RandS
        Overconsumption40_Try = zeros(40,8760);
        for k = 1:40
            Abo = k/2;
            Test = Cons_RandS(g,i);
            for i = 1:8760
                    if Cons_RandS(g,i) > Abo
                        New_Sub(k,g) = New_Sub(k,g)+Sub_Energy_P*Cons_RandS(g
    ,i)+(Cons_RandS(g,i)-Abo)*Sub_Excess40;
                        Overconsumption40_Try(k,i) = (Cons_RandS(g,i)-Abo);
                    else
                        New_Sub(k,g) = New_Sub(k,g)+Sub_Energy_P*Cons_RandS(g
    ,i);
                    end
            end
            New_Sub(k,g) = New_Sub(k,g)+Sub_Cap40*Abo+Sub_Fixed_P;
        end
        [Sub_Tariff40(g,1), Position_40] = min(New_Sub(:,g));
        Sub_Power40(g,1) = Position_40/2;
        Overconsumption40(g,:) = Overconsumption40_Try(Position_40,:);
    end
end
```

Listing 8.2: OptimalSubscription: The MATLAB function for Statnett's Model for Temperature Correction

```
%% Creating Variables for consumption
if  exist('Power_Enebolig') == 0
    Defining_Variables;
end
Power_Enebolig(isnan(Power_Enebolig))=0;
Dato_Enebolig(isnan(Dato_Enebolig))=0;
Metering = zeros(10,2);
Cons = zeros(26,8760);
Date = zeros(26,8760);


k=1;
for i = 1:length(Power_Enebolig(:,1))
    if nnz(Power_Enebolig(i,:)) < 8750
        Power_Enebolig(i,:) = zeros(1,8761);
    end
    if sum(Power_Enebolig(i,:)) ~= 0
        Cons(k,:) = Power_Enebolig(i,1:8760);
        Metering(k,1) = KundeNummer_Enebolig(i,1);
        Metering(k,2) = KundeNummer_Enebolig(i,2);
        Date(k,:) = Dato_Enebolig(i,1:8760);
        k = k+1;
    end
end

Cons(25,:)=[Power_Enebolig(26,1:find(Power_Enebolig(26,:)~=0,1))
    Power_Enebolig(26,Power_Enebolig(26,:)~=0)];
Date(25,:)=Dato_Enebolig(26,Dato_Enebolig(26,:)~=0);
%% Defining Variables

Energy_FixedP           = 1749; % Kr/year
Energy_EnergyP          = 0.194; % Kr/kWh
Energy_Cost             = 0;


Sub_Fixed               = 1060; % Kr/year
Sub_Cap60               = 720; % Kr/kWh/h/year
Sub_Cap40               = 480; % Kr/kWh/h/year
Sub_EnergyP             = 0.05; %Kr/kWh
Sub_Excess40            = 15.85; % Kr/kWh
Sub_Excess60            = 0.82;
Sub_Cost                = 0;

%% Finding the Energy Tariff for all consumers
Energy_Tariff = zeros(125,1);
Energy_Tariff_Energy = zeros(125,1);

for i = 1:125
    Energy_Tariff(i,1) = Energy_FixedP+Energy_EnergyP*sum(Cons(i,:));
    Energy_Tariff_Energy(i,1) = Energy_EnergyP*sum(Cons(i,:));
end


%% Finding the Optimal Subscription for all consumers with Sub = 60
New_Sub = zeros(20,1);
```

```
Old_Sub = zeros(20,1);
k = 1;
Overconsumption60_Try = zeros(20,8760);
Underconsumption60_Try = zeros(20,8760);
Sub_Power60 = zeros(125,1);
Sub_Cost60 = zeros(125,1);
Overconsumption60 = zeros(125,8760);
Underconsumption60 = zeros(125,8760);

Overconsumption_Cost60_Try = zeros(20,1);
Sub_Energy_Cost60_Try = zeros(20,1);
Overconsumption_Cost60 = zeros(125,1);
Sub_Energy_Cost60 = zeros(125,1);
Sub_Sub_Cost60 = zeros(125,1);

for j = 1:125
    New_Sub = zeros(20,1);
    Old_Sub = zeros(20,1);
    Overconsumption60_Try = zeros(20,8760);
    Underconsumption60_Try = zeros(20,8760);
    Sub_Energy_Cost60_Try = zeros(20,1);
    Overconsumption_Cost60_Try = zeros(20,1);
    for k = 1:20
      Abo = k/2;
      Test = Power(i);
      for i = 1:8760
        if Cons(j,i) > Abo
New_Sub(k) = New_Sub(k)+Sub_EnergyP*Cons(j,i)+(Cons(j,i)-Abo)*Sub_Excess60;
Overconsumption60_Try(k,i) = (Cons(j,i)-Abo);
Sub_Energy_Cost60_Try(k) = Sub_Energy_Cost60_Try(k)+Sub_EnergyP*Cons(j,i);
Overconsumption_Cost60_Try(k) = Overconsumption_Cost60_Try(k)+(Cons(j,i)-Abo)*Sub_Excess60;
        else
New_Sub(k) = New_Sub(k)+Sub_EnergyP*Cons(j,i);
Underconsumption60_Try(k,i) = abs((Cons(j,i)-Abo));
Sub_Energy_Cost60_Try(k) = Sub_Energy_Cost60_Try(k)+Sub_EnergyP*Cons(j,i);
        end
      end
      New_Sub(k) = New_Sub(k)+Sub_Cap60*Abo+Sub_Fixed;
    end
    [Sub_Cost60(j,1), Position] = min(New_Sub(:,1));
    Sub_Power60(j,1) = Position/2;
    Overconsumption60(j,:) = Overconsumption60_Try(Position,:);
    Underconsumption60(j,:) = Underconsumption60_Try(Position,:);
    Sub_Energy_Cost60(j,1) = Sub_Energy_Cost60_Try(Position);
    Overconsumption_Cost60(j,1) = Overconsumption_Cost60_Try(Position);
    Sub_Sub_Cost60(j,1) = Sub_Power60(j,1)*Sub_Cap60;
end

%% Finding the Optimal Subscription for all consumers with Sub = 60
New_Sub = zeros(20,1);
Old_Sub = zeros(20,1);
k = 1;
Overconsumption60_Try = zeros(20,8760);
Underconsumption60_Try = zeros(20,8760);
Sub_Power60 = zeros(125,1);
Sub_Cost60 = zeros(125,1);
```

```
Overconsumption60 = zeros(125,8760);
Underconsumption60 = zeros(125,8760);

Overconsumption_Cost60_Try = zeros(20,1);
Sub_Energy_Cost60_Try = zeros(20,1);
Overconsumption_Cost60 = zeros(125,1);
Sub_Energy_Cost60 = zeros(125,1);
Sub_Sub_Cost60 = zeros(125,1);

k = 1;
Overconsumption40_Try = zeros(40,8760);
Underconsumption40_Try = zeros(40,8760);
Sub_Power40 = zeros(125,1);
Sub_Cost40 = zeros(125,1);
Overconsumption40 = zeros(125,8760);
Underconsumption40 = zeros(125,8760);

Overconsumption_Cost40 = zeros(125,1);
Sub_Energy_Cost40 = zeros(125,1);
Sub_Sub_Cost40 = zeros(125,1);

for j = 1:125
        New_Sub = zeros(40,1);
        Old_Sub = zeros(40,1);
        Sub_Energy_Cost60_Try = zeros(40,1);
        Overconsumption_Cost60_Try = zeros(40,1);
        for k = 1:40
            Abo = k/2;
            Test = Power(i);
            for i = 1:8760
                    if Cons(j,i) > Abo
                        New_Sub(k) = New_Sub(k)+Sub_EnergyP*Cons(j,i)+(Cons(j,i)-Abo)*Sub_Excess40;
                        Overconsumption40_Try(k,i) = (Cons(j,i)-Abo);
                        Sub_Energy_Cost60_Try(k) = Sub_Energy_Cost60_Try(k)+Sub_EnergyP*Cons(j,i);
                        Overconsumption_Cost60_Try(k) = Overconsumption_Cost60_Try(k)+(Cons(j,i)-Abo)*Sub_Excess40;
                    else
                        New_Sub(k) = New_Sub(k)+Sub_EnergyP*Cons(j,i);
                        Underconsumption40_Try(k,i) = abs((Cons(j,i)-Abo));
                        Sub_Energy_Cost60_Try(k) = Sub_Energy_Cost60_Try(k)+Sub_EnergyP*Cons(j,i);
                    end
            end
            New_Sub(k) = New_Sub(k)+Sub_Cap40*Abo+Sub_Fixed;
        end
        [Sub_Cost40(j,1), Position] = min(New_Sub(:,1));
        Sub_Power40(j,1) = Position/2;
        Overconsumption40(j,:) = Overconsumption40_Try(Position,:);
        Underconsumption40(j,:) = Underconsumption40_Try(Position,:);
        Sub_Energy_Cost40(j,1) = Sub_Energy_Cost60_Try(Position);
        Overconsumption_Cost40(j,1) = Overconsumption_Cost60_Try(Position);
        Sub_Sub_Cost40(j,1) = Sub_Power40(j,1)*Sub_Cap40;
end
```

Listing 8.3: MovedCons: The MATLAB function for Statnett's Model for Temperature Correction

```matlab
Cons_F = Cons;
CountTimer = 24;
C = CountTimer/2;
P_Moved = 0;
Percent_Moved = 1;
P_Left = 0;

%% For loop for all consumers
for k = 1:125
    for i = 1:8760
        if Overconsumption60(k,i) ~= 0
            P_Moved = Overconsumption60(k,i)*Percent_Moved;
            if i-C > 0 && i+C <= 8760
                for j = 1:CountTimer
                    if mod(j,2)
                        t = ceil(j/2);
                        P_Left = 0;
                        if Underconsumption60(k,i+t) ~= 0 && i+t > 0 && i+t<= 8760 && P_Moved ~= 0

                            P_Left = Underconsumption60(k,i+t);
                            if P_Left < P_Moved && Underconsumption60(k,i+t)-P_Left >= 0 && Underconsumption60(k,i+t) >= 0
                                P_Moved = P_Moved-P_Left;
                                Cons_F(k,i) = Cons_F(k,i)-P_Left;
                                Cons_F(k,i+t) = Cons_F(k,i+t)+P_Left;
                                Underconsumption60(k,i+t) = Underconsumption60(k,i+t)-P_Left;
                            elseif P_Left >= P_Moved && Underconsumption60(k,i+t)-P_Left >= 0 && Underconsumption60(k,i+t) >= 0
                                Cons_F(k,i) = Cons_F(k,i)-P_Moved;
                                Cons_F(k,i+t) = Cons_F(k,i+t)+P_Moved;
                                Underconsumption60(k,i+t) = Underconsumption60(k,i+t)-P_Moved;
                                break;
                            end
                        end
                    elseif ~mod(j,2)
                        t = j/2;
                        P_Left = 0;
                        if Underconsumption60(k,i-t) ~= 0 && i-t > 0 && i-t<= 8760 && P_Moved ~= 0
                            P_Left = Underconsumption60(k,i-t);
                            if P_Left < P_Moved && Underconsumption60(k,i-t)-P_Left >= 0 && Underconsumption60(k,i-t) >= 0
                                P_Moved = P_Moved-P_Left;
                                Cons_F(k,i) = Cons_F(k,i)-P_Left;
                                Cons_F(k,i-t) = Cons_F(k,i-t)+P_Left;
                                Underconsumption60(k,i-t) = Underconsumption60(k,i-t)-P_Left;
                            elseif P_Left >= P_Moved && Underconsumption60(k,i-t)-P_Left >= 0 && Underconsumption60(k,i-t) >= 0
                                Cons_F(k,i) = Cons_F(k,i)-P_Moved;
                                Cons_F(k,i-t) = Cons_F(k,i-t)+P_Moved;
                                Underconsumption60(k,i-t) = Underconsumption60(k,i-t)-P_Moved;
```

```
                            break;
                        end
                    end
                end
            end
        elseif i-CountTimer <= 0
            for j = 1:CountTimer*2
                if mod(j,2)
                    t = ceil(j/2);
                    P_Left = 0;
                    if Underconsumption60(k,i+t) ~= 0 && i+t > 0 && i+t<= 8760 && P_Moved ~= 0
                        P_Left = Underconsumption60(k,i+t);
                        if P_Left < P_Moved && Underconsumption60(k,i+t)-P_Left >= 0 && Underconsumption60(k,i+t) >= 0
                            P_Moved = P_Moved-P_Left;
                            Cons_F(k,i) = Cons_F(k,i)-P_Left;
                            Cons_F(k,i+t) = Cons_F(k,i+t)+P_Left;
                            Underconsumption60(k,i+t) = Underconsumption60(k,i+t)-P_Left;
                        elseif P_Left >= P_Moved && Underconsumption60(k,i+t)-P_Left >= 0 && Underconsumption60(k,i+t) >= 0
                            Cons_F(k,i) = Cons_F(k,i)-P_Moved;
                            Cons_F(k,i+t) = Cons_F(k,i+t)+P_Moved;
                            Underconsumption60(k,i+t) = Underconsumption60(k,i+t)-P_Moved;
                            break;
                        end
                    end
                elseif ~mod(j,2)
                    t = j/2;
                    P_Left = 0;
                    if i-t > 0
                        if Underconsumption60(k,i-t) ~= 0 && i-t<= 8760 && P_Moved ~= 0
                            P_Left = Underconsumption60(k,i-t);
                            if P_Left < P_Moved && Underconsumption60(k,i-t)-P_Left >= 0 && Underconsumption60(k,i-t) >= 0
                                P_Moved = P_Moved-P_Left;
                                Cons_F(k,i) = Cons_F(k,i)-P_Left;
                                Cons_F(k,i-t) = Cons_F(k,i-t)+P_Left;
                                Underconsumption60(k,i-t) = Underconsumption60(k,i-t)-P_Left;
                            elseif P_Left >= P_Moved && Underconsumption60(k,i-t)-P_Left >= 0 && Underconsumption60(k,i-t) >= 0
                                Cons_F(k,i) = Cons_F(k,i)-P_Moved;
                                Cons_F(k,i-t) = Cons_F(k,i-t)+P_Moved;
                                Underconsumption60(k,i-t) = Underconsumption60(k,i-t)-P_Moved;
                                break;
                            end
                        end
                    end
                end
            end
        elseif i+CountTimer > 8760
            for j = 1:CountTimer*2
```

```
                   if mod(j,2)
                       t = ceil(j/2);
                       P_Left = 0;
                       if i+t <= 8760
                           if Underconsumption60(k,i+t) ~= 0 && i+t > 0 && P_Moved ~= 0
                               P_Left = Underconsumption60(k,i+t);
                               if P_Left < P_Moved && Underconsumption60(k,i+t)-P_Left >= 0 && Underconsumption60(k,i+t) >= 0
                                   P_Moved = P_Moved-P_Left;
                                   Cons_F(k,i) = Cons_F(k,i)-P_Left;
                                   Cons_F(k,i+t) = Cons_F(k,i+t)+P_Left;
                                   Underconsumption60(k,i+t) = Underconsumption60(k,i+t)-P_Left;
                               elseif P_Left >= P_Moved && Underconsumption60(k,i+t)-P_Left >= 0 && Underconsumption60(k,i+t) >= 0
                                   Cons_F(k,i) = Cons_F(k,i)-P_Moved;
                                   Cons_F(k,i+t) = Cons_F(k,i+t)+P_Moved;
                                   Underconsumption60(k,i+t) = Underconsumption60(k,i+t)-P_Moved;
                                   break;
                               end
                           end
                       end
                   elseif ~mod(j,2)
                       t = j/2;
                       P_Left = 0;
                       if i-t <= 8760
                           if Underconsumption60(k,i-t) ~= 0 && i-t > 0 && P_Moved ~= 0
                               P_Left = Underconsumption60(k,i-t);
                               if P_Left < P_Moved && Underconsumption60(k,i-t)-P_Left >= 0 && Underconsumption60(k,i-t) >= 0
                                   P_Moved = P_Moved-P_Left;
                                   Cons_F(k,i) = Cons_F(k,i)-P_Left;
                                   Cons_F(k,i-t) = Cons_F(k,i-t)+P_Left;
                                   Underconsumption60(k,i-t) = Underconsumption60(k,i-t)-P_Left;
                               elseif P_Left >= P_Moved && Underconsumption60(k,i-t)-P_Left >= 0 && Underconsumption60(k,i-t) >= 0
                                   Cons_F(k,i) = Cons_F(k,i)-P_Moved;
                                   Cons_F(k,i-t) = Cons_F(k,i-t)+P_Moved;
                                   Underconsumption60(k,i-t) = Underconsumption60(k,i-t)-P_Moved;
                                   break;
                               end
                           end
                       end
                   end
               end
           end
       end
    end
end
```

Listing 8.4: Defining_Variables: The MATLAB function for Statnett's Model for Temperature Correction

```

% Legger inn all excel-dataen inn i matlab
b = [];
for i=1:12 %Bruker for-lkke til  g gjennom all dataen og sette de sammen til en matrise
    name=['Maaned' num2str(i) '.xlsx'];
    a=xlsread(name);
    [n1 , n2] = size(a);
    [n m]=size(b);
    b((n+1:n+n1),1) = a(:,1);
    b((n+1:n+n1),2) = a(:,2);
    b((n+1:n+n1),3) = a(:,3);
end
Anleggsinfo = xlsread('Anleggsinfo'); %legger til anleggsid i en egen matrise





Power = zeros(100,8761);
Dato = zeros(100,100);
k = 1;
KundeNummer = zeros(100,2);
KundeNummer(1,1) = b(1,1);


v = 1;
KundeNr = zeros(100,2);
KundeOld = zeros(100,1);

Power2 = zeros(100,8760);
Dato2 = zeros(100,8760);

KundeNummer_Enebolig = zeros(5,2);
KundeNummer_Bolig = zeros(5,2);
KundeNummer_Hytte = zeros(5,2);
KundeNummer_Naering = zeros(5,2);

i1 = 1;
i2 = 1;
i3 = 1;
i4 = 1;


for i = 2:475
    flag = 0;
        for j = 1:length(b(:,1))
            for k = 1:i-1
                if KundeNummer(k,1) ~= b(j,1)
                        flag = 1;
                end
                if KundeNummer(k,1) == b(j,1)
                    flag = 0;
                    break;
                end
```

```
            end
            if flag == 1
                KundeNummer(i,1) = b(j,1);
                for g = 1:length(Anleggsinfo(:,1))
                    if KundeNummer(i,1) == Anleggsinfo(g,1) %&& Anleggsinfo(j,4) ~= 0
                        KundeNummer(i,2) = Anleggsinfo(g,4);
                        if Anleggsinfo(g,4) == 1
                            KundeNummer_Enebolig(i1,2) = Anleggsinfo(g,4);
                            KundeNummer_Enebolig(i1,1) = KundeNummer(i,1);
                            i1 = i1+1;
                        elseif Anleggsinfo(g,4) == 2
                            KundeNummer_Bolig(i2,2) = Anleggsinfo(g,4);
                            KundeNummer_Bolig(i2,1) = KundeNummer(i,1);
                            i2 = i2+1;
                        elseif Anleggsinfo(g,4) == 3
                            KundeNummer_Hytte(i3,2) = Anleggsinfo(g,4);
                            KundeNummer_Hytte(i3,1) = KundeNummer(i,1);
                            i3 = i3+1;
                        elseif Anleggsinfo(g,4) == 4
                            KundeNummer_Naering(i4,2) = Anleggsinfo(g,4);
                            KundeNummer_Naering(i4,1) = KundeNummer(i,1);
                            i4 = i4+1;
                        end
                    end
                end
                break;
            end
        end
end
k = 1;
Power_Enebolig = zeros(10,8760);
Power_Bolig = zeros(10,8760);
Power_Hytte = zeros(10,8760);
Power_Naering = zeros(1,8760);

Dato_Enebolig = zeros(10,8760);
Dato_Bolig = zeros(10,8760);
Dato_Hytte = zeros(10,8760);
Dato_Naering = zeros(1,8760);

i1 = 1;
i2 = 1;
i3 = 1;
i4 = 1;

for i = 1:475
    v1 = 1;
    v2 = 1;
    v3 = 1;
    v4 = 1;
    k1 = 0;
    k2 = 0;
    k3 = 0;
    k4 = 0;
    for j = 1:length(b(:,1))
        if KundeNummer(i,1) == b(j,1)
```

```
            if KundeNummer(i,2) == 1
                Power_Enebolig(i1,v1) = b(j,3);
                Dato_Enebolig(i1,v1) = b(j,2);
                v1 = v1+1;
                k1 = 1;
            elseif KundeNummer(i,2) == 2
                Power_Bolig(i2,v2) = b(j,3);
                Dato_Bolig(i2,v2) = b(j,2);
                v2 = v2+1;
                k2 = 1;
            elseif KundeNummer(i,2) == 3
                Power_Hytte(i3,v3) = b(j,3);
                Dato_Hytte(i3,v3) = b(j,2);
                v3 = v3+1;
                k3 = 1;
            elseif KundeNummer(i,2) == 4
                Power_Naering(i4,v4) = b(j,3);
                Dato_Naering(i4,v4) = b(j,2);
                v4 = v4+1;
                k4 = 1;
            end
        end
    end
    if k1 == 1
        i1 = i1+1;
    end
    if k2 == 1
        i2 = i2+1;
    end
    if k3 == 1
        i3 = i3+1;
    end
    if k4 == 1
        i4 = i4+1;
    end
end





Power_Bolig(isnan(Power_Bolig))=0;
Power_Hytte(isnan(Power_Hytte))=0;
Power_Naering(isnan(Power_Naering))=0;






% for i = 1:475
%     if sum(Power(i,:)) ~= 0
%         Power2(k,:) = Power(i,1:8760);
%         KundeNr(k,1) = KundeNummer(i,1);
%         KundeNr(k,2) = KundeNummer(i,2);
%         Dato2(k,:) = Dato(i,1:8760);
%         k = k+1;
```

```
%       end
% end
%
% if nnz(Power_Enebolig(i1 -1,:)) < 8750
%           Power_Enebolig(i1 -1,:) = zeros(1,8760);
%       end
%       if nnz(Power_Bolig(i2 -1,:)) < 8750
%           Power_Bolig(i2 -1,:) = zeros(1,8760);
%       end
%       if nnz(Power_Hytte(i3 -1,:)) < 8750
%           Power_Hytte(i3 -1,:) = zeros(1,8760);
%       end
%       if nnz(Power_Naering(i4 -1,:)) < 8750
%           Power_Naering(i4 -1,:) = zeros(1,8760);
%       end

%Power2(50,:)=[Power(51,1:find(Power(51,:)~=0,1))    Power(51,Power(51,:)~=0)
    ];
```