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Economic aspects of energy transition:

issues for electrification caused by market distortions

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Abstract

This thesis examines electricity distribution pricing in Finland. I explain how electricity distributors are regulated in Finland, and how this regulation method can result in market inefficiencies. Then I will show that this is indeed the case, and there is a significant difference between the marginal costs and marginal prices of electricity distributors, and this causes a market distorting price wedge.

I estimate the size of the market distorting price wedge and using this information, I calculate the increase in marginal costs for two products: electric heating in houses and electric vehicles. This exercise demonstrates that the price wedge has a positive effect on the marginal costs of using electricity intensive products, and thus affects consumer choices.

This issue is important and topical, because the market distortion studied in this paper increase the barriers of adopting low-carbon alternatives to carbon intensive products such as oil-heated housing and conventional gasoline powered vehicles. Removing this market distorting barrier would help reduce greenhouse gas emissions by accelerating electrification.

Keywords electricity distribution, market distortion, monopoly regulation, energy transition

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Tiivistelmä

Tämä opinnäytetyö tutkii sähkön jakelua suomessa. Työssä käyn läpi, miten suomessa säännellään sähkönjakeluyhtiöitä, ja näytän, että nykyinen sääntelymalli antaa mahdollisuuden sähkön jakelun markkinavääristymiin. Tämä jälkeen näytän, että suomen sähkönjakelumarkkinassa todella on markkinavääristymää. Näytän, että markkinavääristymä johtuu sähkönsiirtoyhtiöiden hinnoittelumallista ja erosta, jotka sähkön siirron rajakustannusten ja rajahintojen välillä on.

Työssä arvioin markkinaa vääristävän hintakiilan koon ja käyttäen tätä tulosta, lasken miten tämä vaikuttaa sähkölämmitteisen omakotitalon lämmittämisen sekä sähköauton käytön marginaalikustannuksiin. Tämä harjoitus havainnollistaa, että markkinaa vääristävä hintakiila luo positiivista painetta kuluttajien rajakustannuksiin, ja tätä kautta vääristää kuluttajien ostopäätöksiä.

Aihe on tärkeä ja ajankohtainen, koska markkinavääristymä, jota tämä työ käsittelee, nostaa kuluttajien kynnystä ottaa käyttöön vähäpäästöisiä vaihtoehtoja perinteisiin korkeapäästöisiin tuotteisiin, kuten öljylämmitystä omakotitaloon ja polttomoottoriautoihin. Tämän kynnyksen poistaminen edesauttaisi kasvihuonepäästöjen vähentämistä edistämällä sähköistymistä.

Avainsanat sähkön jakelu, markkinavääristymä, monopolisääntely, sähköistyminen

Contents

1 Introduction

Electrification is an important movement in the modern world. Since climate change has become such an important and serious issue, it is necessary to look for methods to mitigate and reduce carbon emissions, and thus climate change. One way to accomplish this is electrification: electricity can be produced in carbon-free ways, such as solar power, wind power, hydropower, or nuclear power. This green electricity can be used to replace traditional carbon intensive products. Some examples of this are for instance replacing traditional combustion engine vehicles with electric vehicles and replacing carbon-intensive domestic heating with electric heating.

Part of decarbonizing electricity is decarbonizing electricity production, and this is well underway. According to Heal (2020), the share of electric power generated by coal in the US has fallen from over 50% to 21% in the last fifteen years. In the U.K. the same is happening, with the share of coal-generated power falling from 30% to 5% between 2014 and 2018.

The second part of decarbonizing electricity is incentivizing consumers to switch from high carbon-intensive products to low carbon-intensive products. In order to reach these goals of carbon mitigation, consumers need to have large enough incentives to use electric alternatives to carbon-intensive ones. A large incentive that dictates consumer choices is naturally pricing.

From a consumer's point of view, electricity pricing is made up of three separate components: the price of the electricity itself, the price of distributing electricity and a tax. Although consumers make their consumption decision based on the combined marginal price all three of these components, they are still three separate components, and in Finland the actual electricity and its distribution are often provided by two different companies.

This thesis will focus on electricity distribution for consumers in Finland. This thesis will solely focus on consumers, as electricity distribution for industrial clients is very different to consumer electricity consumption. Industrial customers, such as factories, can often have their own on-site electricity production plant that makes the conversation about electricity distribution obsolete. Even if this is not the case, the prices charged for industrial clients can often vary from consumer prices by a large margin.

Electricity distribution is a textbook example of a natural monopoly, and this is why electricity distribution is regulated by the government. This thesis will dive deeper into how electricity distribution networks are currently regulated in Finland. In short, the main objective of this regulation system is to ensure that electricity distributors cannot make excessive profits. This is done by setting an upper bound for the profits distribution network operators (DNOs) can make, ensuring that in the long term DNOs do not make excessive profits.

Although this regulation is necessary to protect consumers by preventing the DNOs from abusing their monopoly power, the current regulation provides no incentives or regulation for DNOs to create pricing strategies that maintain an efficient electricity distribution market. This regulation system makes it possible for DNOs to create a pricing strategy where their fixed fees and variable fees are balanced in way that creates a market distortion. The underlying reason for this is that the companies have no monetary incentive to create pricing structures that facilitate an efficient market, as the current regulatory system does not encourage this.

After explaining how the current regulatory system enables the existence of an inefficient market, I will conduct an empirical analysis using price and cost data from Finnish distribution networks. I will show how that this is indeed the case: marginal prices of electricity distribution do not match the marginal costs of electricity distribution. This causes a price wedge that leads to market distortions, and the result of this is underconsumption of electricity and increased marginal costs for using electricity intensive products.

This price wedge causes two problems. Firstly, it is not desirable to have any market operating inefficiently, as in such a case net welfare is not maximized. Secondly, specifically this electricity distribution market inefficiency discourages consumers from purchasing low-emission electric alternatives to traditional high emission alternatives, such as oil-based home heating systems and combustion engine vehicles. Considering that electrification is desirable as it facilitates transitioning from fossil fuels to green, more ecological alternatives, this price wedge is an obstacle that hinders the goal of electrification.

1.1 Related literature

Monopolies and monopoly pricing within the context of electricity distribution has been studied for a while now. Electricity distribution is a classic example of a natural monopoly, and thus the problems this poses, and potential solutions, have been extensively researched.

Many models have been proposed to solve the problem of minimizing the deadweight loss that can arise from a monopoly. This includes models proposing price discrimination with linear tariffs (Ramsey, 1927; Boiteux, 1960; Boiteux, 1971), two-part pricing (Feldstein, 1972; Littlechild, 1975) and other non-linear pricing models (Wilson, 1997; Laffont et al., 1998). Despite this extensive research, the consensus is that utility rates, in monopolistic markets such as electricity distribution, do not closely approximate marginal costs (Borenstein & Bushnell, 2021).

Empirical research on this topic has been done, for example by Borenstein & Bushnell (2021). They estimated the prices US electricity consumers face. This analysis is conducted by aggregating the price of electricity, the price of electricity distribution, and tax into one product. They found that the prices generally exceed marginal costs.

A similar study has not been done in Finland, and this is what this thesis aims to do. The Finnish energy market has been studied in other contexts, such examining how energy prices affect consumer choices (Sahari, 2019). This thesis attempts to provide a similar analysis as Borenstein & Bushnell but for the Finnish market. That said, this thesis will be narrower the study conducted by Borenstein & Bushnell, as I examine purely the energy distribution market, and not the energy market as a whole.

2 Institutions and data

This section is an overview of the private companies and institutions that jointly form the electricity distribution network in Finland, i.e. the firms that create the distribution network and the government institutions that regulate these firms. This section is meant to provide context to the efficiency analysis of electricity distribution pricing to come and to highlight how the current regulatory model enables an inefficient market. I will also discuss the data that I will use, explaining where the different data sets used in this work come from and how they are gathered.

2.1 Natural monopolies

Electricity distribution firms are a textbook example of a natural monopoly due to the high fixed cost of building an electricity distribution network. These costs come from all of the physical hardware needed to build an electricity distribution network, such as power lines and substations. Because of these high costs, it is not efficient to have multiple electricity distribution firms competing in the same market, hence making it a great example of a natural monopoly.

Since monopolies often raise issues of excessive market power, government intervention is often necessary to prevent firms with monopoly power from using their dominant market position to maximize their profits by inflating prices and reducing supply. These inflated prices and reduced supply would reduce consumer welfare, and consumers cannot participate in "vote with your wallet" behavior as the monopolist is the only firm in the market. Government intervention is especially critical with typical examples of natural monopolies like electricity distribution or water distribution, since they are essential components of a functioning modern society.

There are typically other issues caused by excessive market power besides inflated prices that harm consumers. These include reduced incentives for innovation, reduced quality and limiting supply. The Finnish Energy Authority (FEA) has implemented regulation to specifically address these issues, such as providing incentives for distribution network operators to improve the quality of their networks and to facilitate innovation.

2.2 Overview of the Finnish regulatory system

Currently in Finland there are 77 firms that each operate their own electricity distribution networks. For the rest of this thesis, these firms will be referred to as distribution network operators (DNOs). The way that these DNOs are regulated is by setting a maximum for the adjusted earnings that these firms are allowed to make (Energiavirasto, 2021). The FEA calculates a reasonable return on capital using the weighted average cost of capital (WACC) method. The FEA uses this reasonable return to constrain the DNOs adjusted earnings in an effort to ensure that electricity distribution is priced fairly, and that the excessive market power held by DNOs is not reflected in excessive electricity distribution prices for consumers.

The earnings of DNOs are also adjusted by incentivizing DNOs to maintain quality in their network, increase efficiency in the operation of the networks, and to incentivize innovation and investment. The methods the FEA uses to calculate and enforce reasonable profits for DNOs, as well as the additional incentivization methods, will be explained and discussed in following sections.

The main goal of the FEA for these regulations is to ensure reasonable pricing and to maintain the quality of electricity distribution services (Energiavirasto, 2021). In addition to these goals, the FEA has secondary objectives in their mandate. These secondary objectives include fairness, developing the distribution network, ensuring longevity of business and efficiency.

The fairness objective means that the FEA wants to ensure that there are no significant income discrepancies between DNO owners and their clients. The development of the network objective is meant to encourage DNOs to build distribution networks that are more stable and reach a larger population. The longevity objective has the goal of ensuring network stability by incentivizing necessary infrastructure investments to maintain and improve the distribution networks. This objective also covers other business areas of the DNOs, to make sure that the firms are financially healthy and stable. The efficiency objective is necessary to mitigate the efficiency problems that arise when dealing with monopolies, and this objective allows the FEA to incentivize DNOs to run their electricity distribution grids as efficiently as possible.

2.3 Challenges in the Finnish market

The Finnish electricity distribution market provides many challenges to DNOs that are unique to Finland. For instance, Finland is a relatively sparsely populated country, which makes it costly to provide good quality, stable electricity networks to rural areas of Finland. The reason for this is that it is simply not commercially profitable for the DNOs to do this, and the FEA has to take this into account when designing the regulatory environment for DNOs.

Another challenge in Finland is that it is a heavily forested country. A significant portion of the electricity distribution network in Finland is still implemented as power lines that run above ground. This is an issue because the combination of above-ground power lines and a forest environment results in the risk of trees falling on power lines. Grid disruptions caused by

falling trees pose a significant cost for DNOs as these disruptions are expensive to fix, especially in sparsely populated areas.

Another recent development in the electricity selling and distribution market in Finland is the deregulation that has taken place in the last decades. In 1995, the regulation of Finnish electricity markets was changed so that the markets for selling and producing electricity became competitive (Kopsakangas-Savolainen, 2002). Before this, they were regulated monopolies similar to the electricity distribution market today. This change fundamentally changed the way the electricity production, selling and distribution markets worked in Finland.

2.4 Adjusted capital and reasonable rates of return for DNOs

This section will explain the methods the FEA uses to calculate the amount of capital a DNO has and how this information is used to calculate a reasonable rate of return for each DNO. This is relevant for the scope of this thesis because in order to understand the potential problems of the regulatory system, it is necessary to understand how the system works.

Since the DNOs operate as regional monopolies, it is necessary to regulate them in some way to ensure reasonable pricing of electricity distribution. In Finland this regulation is implemented by monitoring and regulating DNO profits. The FEA sets a rate of return for DNOs that they should not exceed. This rate of return is based on the capital of the DNOs and is calculated using the WACC method.

The FEA monitors DNO profits in 4-year monitoring periods. The previous cycle was over the years 2016-2019, and the current cycle will run from 2020 to 2023. After each monitoring period, the FEA checks the profits each DNO has made against the reasonable rate of return that the FEA has determined for the DNO in question.

If the DNO exceeds this reasonable rate of return in a monitoring period, they will have to lower their prices for the next period. Conversely, if they earn less than their reasonable rate of return, they will be allowed to charge higher prices for the next monitoring period to compensate for the previous period (Energiavirasto, 2021).

This system is meant to ensure that in the long run, DNOs earn returns set by the reasonable rate of return. Even though DNO profits can fluctuate over the short-term in this system, these fluctuations are smoothed out in the long run.

2.4.1 Adjusted capital for electricity distribution purposes

Since the rate of return is based on the capital of a DNO, the first step in this process is to establish the capital a DNO has invested in its electricity distribution network. The FEA corrects the balance sheets of DNOs by focusing on their non-current network assets, other assets, current assets, equity and borrowed capital.

The most important part here is the non-current network assets, as this section of the balance sheet contains all of the physical capital that constitutes a DNOs electricity distribution network. This includes items like power lines, electricity substations and other physical network capital such as electric equipment, the systems and software serving the use of the electricity network, and the production of electricity network services (Energiavirasto, 2015).

The balance sheet category of non-current network assets is where most of a DNOs assets are, since these items create the electricity distribution network which is typically very expensive. While the FEA does adjust other assets and liabilities besides the non-current network assets, they will not be discussed further here. For details about these see Energiavirasto (2021).

The non-current network assets are adjusted by first calculating their net replacement cost (NRC), which is essentially the cost that the DNO would have to pay in order to replace each component in their distribution network. The NRC is calculated by obtaining average unit prices for each individual network component that a DNO has in their network. It is also necessary to count the number of each individual component that a DNO has deployed in their network.

Multiplying the unit price and quantity of a component together and summing over all of the network components, we get to a networks net replacement cost as seen in equation (1).

$$NRC = \sum_{i=1}^{n} (average\ unit\ price_i * quantity_i) \quad (1)$$

After the net replacement cost of a network is obtained, this estimate is used to calculate the adjusted replacement value (ARV) of the network. The adjusted replacement value takes into account the age and intended lifetime of a network and its distinct components, so essentially this step factors in depreciation of the network. The adjusted replacement value is calculated by adjusting the net replacement costs of each network component by their age and intended lifetime as shown in equations (2) and (3). The age is an average age over all the components in a network.

$$ARV_i = \left(1 - \frac{age_i}{intended\ lifetime_i}\right) * NRC_i \quad (2)$$

$$ARV = \sum_{i=1}^{n} ARV_i \quad (3)$$

These adjustments are done to obtain a better estimate on the value of the electricity distribution network with respect to the age of the network. Typically, these adjustments lead to significantly lower asset values for the network than what the DNOs report in their balance sheets (Energiavirasto, 2020). Using this estimate of the value of the electricity distribution network and the capital invested in the network, we can move on towards calculating a reasonable rate of return for the DNOs.

2.4.2 Cost of equity

Calculating the cost of equity is necessary to calculate the reasonable rate of return with the WACC method in section 2.4.4. The FEA calculates the reasonable cost of equity using the capital asset pricing model (CAPM) as shown in equation (4).

$$C_E = R_f + \beta * \left(R_m - R_f\right) + LP \quad (4)$$

In equation (4) C_E is the cost of equity, R_f is the risk-free rate of return, R_m is the return of the market as a whole and LP is an illiquidity premium. The beta is a standard component of the CAPM and it is calculated as the covariance between an assets returns and the returns of some benchmark. In other words, the beta represents an assets volatility with respect to the overall market, and thus riskiness.

The CAPM model was developed by (Treynor, 1961), (Sharpe, 1964), (Lintner, 1965), and (Mossin, 1966) and is a very standard model in financial economics. The model used by the FEA differs slightly from the standard CAPM model by adding the illiquidity premium component to the model. This is justified because DNOs have a large portion of illiquid assets, mainly the distribution network. This means that the solvency of a DNO is worse compared to another company with a similar sized balance sheet. This makes a loan given to a DNO riskier than a loan given to other types of firms of similar size. This will be reflected in a higher cost of equity, and this is precisely what the illiquidity premium aims to incorporate into the CAPM.

The FEA uses Finnish government bond yields as a reference for risk-free asset returns and based on this set the market risk premium $\left(R_m - R_f\right)$ at 5% during the previous control period (2016 to 2019). The beta used during the last period is 0.828, indicating a smaller risk than the market as a whole. The illiquidity premium used during the last period is 0.6%.

2.4.3 Cost of debt

The cost of debt (C_D) is calculated by simply adding a premium for debt (DP) to the risk-free interest rate.

$$C_D = R_f + DP \quad (5)$$

The risk-free interest rate here is the same as the risk-free return in the previous section. The risk premium for debt that FEA used in the last period is 1.4%, and this is calculated as an average over the range of the premium as estimated by a third-party consultant. This range is based on risk premiums for European utility companies (including electricity and gas companies) with varying credit ratings, such that the bottom of the range corresponds to risk premiums of companies with good credit ratings and conversely the high end of the range corresponds to risk premiums of companies with bad credit ratings.

2.4.4 Reasonable rate of return

The reasonable rate of return for DNOs is calculated using the weighted average cost of capital (WACC) method. It essentially is a weighted average of cost of equity and cost of debt weighed by the capital structure of the firm. The WACC formula used by the FEA is shown in equation (6).

$$WACC_{post-tax} = C_E * \frac{E}{E+D} + C_D * (1-\tau) * \frac{D}{E+D}$$

(6)

Here C_E and C_D are the costs of equity and debt, E and D is the equity and debt respectively invested into network operations and τ is the tax-rate. FEA assumes a fixed capital structure where debt is assumed to be 40% of total capital and equity is 60% of total capital. This assumption is based on an assessment made by a third-party consult. They conducted a study where they assessed publicly listed network operators' capital structures and found the average DNO capital structure to be 40% debt and 60% equity. In this study it was assumed that the publicly listed DNOs were optimizing their capital structure, and thus this capital structure is optimal for a DNO (Energiavirasto, 2021).

The post-tax WACC of equation (6) is corrected with the tax rate to get the pre-tax WACC and inserting the capital structure values we get equation (7).

$$WACC_{pre-tax} = \frac{WACC_{post-tax}}{(1-\tau)} = \frac{C_E * 0.6}{(1-\tau)} + C_D * 0.4$$

(7)

This pre-tax WACC is the rate of reasonable return the FEA uses to regulate DNO profits. To get to the reasonable returns, we multiply the rate of reasonable returns with the capital a DNO has invested into network operations.

$$R_{pre-tax} = WACC_{pre-trax} * (E+D)$$

(8)

By inserting equation (7) into (8) we get:

$$R_{pre-tax} = \left(\frac{C_E * 0.6}{(1-\tau)} + C_D * 0.4\right) * (E+D)$$

(9)

As we see from equation (9) the profits of a DNO are dependent only on the amount of capital invested into their network operations and the costs of equity and debt. Since the cost of equity and debt is a given for DNOs, the only way they can affect their profits is by changing their invested capital, which means improving their network. It should also be noted that the $E + D$ in these equations compromises the entire capital invested into network operations

and are adjusted as explained in section 2.4.1. Thus, they are not simply the capital invested into network operations as reported by the balance sheets of DNOs.

In summary, the Finnish regulatory model sets a target for DNO profits that is based on their adjusted capital and a reasonable rate of return. The regulation in no way takes a stance on the tariff structures DNOs use to price their services, and this is the source of the issue. The DNOs are not incentivized to set their prices equal to marginal costs, which would result in an optimal market allocation. Instead, they can freely choose their tariff structures themselves as long as their profits are in line with the regulatory limits, and I will show that this can lead to large differences between marginal costs and marginal prices.

2.5 Incentive correction methods and corrected profits

In addition to the reasonable rate of return that the FEA mandates for DNOs, the FEA also provides four different incentives to motivate the DNOs to maintain and improve their distribution networks in a way that the FEA deems appropriate. These incentives are the investment incentive, the quality incentive, the efficiency incentive, and the innovation incentive. This section will explain the purpose of these incentives, how they work, and how they fit in with the rest of the regulation.

2.5.1 Investment incentive

The investment incentive is meant to motivate DNOs to make cost effective investments into their distribution networks, and to enable investing into replacing parts of the network. This inventive works by calculating the difference between the cost of an investment using the average unit prices, and the cost of the actual investment. The average unit price used is the same average unit price that was previously used when calculating the adjusted capital of a DNO in section 2.4.1.

The total difference between these costs of investments across all the investments a DNO has made is subtracted from the profit a DNO makes. This means that the more cost-effective investments a DNO makes, the more they are allowed to earn profit.

2.5.2 Quality incentive

The Finnish law mandates a certain level of quality that DNOs must provide. The DNOs must have a certain uptime on their network, meaning that if customers of a DNO experience too many power outages the DNO will face repercussions. The FEA aims to incentivize DNOs to

improve the quality of their network beyond the bare minimum mandated by law, and the quality incentive is the way that the FEA aims to achieve this goal.

The quality incentive works by internalizing the cost of power outages for DNOs. Both planned and unplanned power outages are included in this calculation. The cost is internalized by calculating the of power outages, and then similarly to the investment incentive either reducing or increasing the allowed profit of a DNO depending on the cost of power outages.

The cost of power outages is calculated using unit prices for different types of power outages. These prices have been determined by an investigation by a third-party consultant. In essence, these prices are multiplied together with the time of each type of power outage to reach a total cost figure. For details on this calculation see (Energiavirasto, 2021).

2.5.3 Efficiency incentive

The efficiency incentive is meant to encourage DNOs to operate in an efficient manner. In practice this means minimizing costs and maximizing results. The efficiency incentive is formed by six factors: a general efficiency target, the variables of company-specific efficiency monitoring, a company-specific efficiency target, a reference level for company-specific efficiency costs, company-specific realized efficiency costs, and the efficiency incentive in the calculation of adjusted profits.

General efficiency target

The purpose of this target is to incentivize distributors to make their operations more efficient. According to the FEA, this is a natural goal to combat the efficiency problems natural monopolies cause.

The variables of company-specific efficiency monitoring

The FEA details what DNO-specific variables they will consider for company efficiency. The FEA splits these variables into three categories: input variables, output variables and environment variables.

The input variables of a DNO that the FEA monitors are controllable operative expenses (called KOPEX) and the electricity grid re-purchase value.

The output variables of a DNO that the FEA monitors are the amount of energy transferred in GWh, the length of the grid in km, the amount of customer access points, and the costs of interruption.

The environment variable the FEA considers it the ratio of subscriptions to the amount of customer access points that the DNO has. This variable is meant to incorporate the increased costs a DNO faces from operating in a sparsely populated area.

Company-specific efficiency target

The purpose of the company-specific efficiency target is to incentivize DNOs that have been identified as inefficient to become more efficient. To determine the efficiency of DNOs, a third-party consultant developed a method that is based on the StoNED method (Stochastic Non-smooth Envelopment of Data). This thesis will not go into the details of this model specification or how it is used to estimate firm efficiency. For details on this, see (Energiavirasto, 2021).

Reference level for company-specific efficiency costs

A reference level for efficiency is needed as a benchmark that can be used when evaluating company efficiency. For this benchmark, the FEA uses reasonably controllable operative expenses (SKOPEX). Again, for details on how this is calculated see (Energiavirasto, 2021).

Company-specific realized efficiency costs

These costs are calculated annually, using the methods described above.

The efficiency incentive in the calculation of adjusted profits

The efficiency incentive, which consist of the five parts listed above, is subtracted from the DNOs adjusted profits. In practice, this means that the more efficient the firm is, according to this efficiency metric, the more profits a firm is allowed to make before they reach the hard profit limit set by the FEA.

The effect of the efficiency incentive is calculated as the difference between the reference level for efficiency costs and company-specific realized efficiency costs. The variables included in this calculation are the ones listed above. The FEA also sets an upper limit on the efficiency incentive, such that it can be at most 20% of a DNOs yearly reasonable profit.

2.5.4 Innovation incentive

The innovation incentive is meant to encourage innovation for the DNOs. This is meant to address one of the classical problems with a natural monopoly, which is reduced innovation. The innovation incentive effectively subsidizes research and development for DNOs.

The DNOs can file research and development (R&D) costs so that they are reduced from their allowed earnings. The FEA has set criteria to what R&D costs are allowed to de deducted from earnings. These costs must be associated with creating new information, technology, a product, or a new process. The results of the R&D must also be made public, so that for instance other DNOs can freely use the findings.

2.6 Potential problems of the regulatory system

One problem that exists because of the way the regulation system works is the problem that DNOs do not have an incentive to ensure market efficiency. In a normal situation, market efficiency is ensured by the market: inefficient firms cannot afford to stay in the market, and they are left with the options of increasing efficiency or leaving the market.

This is not the case with the electricity market, since there is no market pressure that would affect prices. While the regulation implemented by the FEA does ensure that consumers do not pay excessive amounts for electricity distribution, the regulation does not ensure that DNOs set their marginal and fixed prices in a way that facilitates an efficient market. From a DNOs point of view, they receive the same amount of revenue regardless, so it makes no difference. This topic is what this thesis will focus on: assessing if indeed DNO pricing structures facilitate an inefficient market allocation, and if so, how extensive are the repercussions of this.

Another problem worth considering is that it is difficult to accurately assess costs of a monopoly. The monopoly itself has the best knowledge on its own costs, which is why it is difficult for a regulator to accurately assess the monopolies costs, and which is why regulators often rely on monopolies reporting their costs to regulators. For example, the DNOs are responsible for reporting many key figures that the FEA uses to evaluate the reasonable rate of return. This is a clear moral hazard problem, as the monopolies profits depend on their self-reported costs: only the monopoly knows its true costs, and it is difficult to effectively and efficiently monitor that the monopoly truthfully reports these costs.

This a classic problem with monopoly regulation, and because of this the problem has been extensively researched. Solutions to this problem exist, such as credible threats of fines that do not make it profitable for the monopoly to report untruthfully. Because of existing research and solutions on this problem I do not see this as a very serious problem in the Finnish electricity distribution market. It is good to keep in mind that monopoly regulation is difficult due to many reasons, and the problem of pricing structures is by no means the only problem that DNO monopoly regulation needs to solve. With that said, this thesis will mainly focus on the problem of DNO pricing structures.

In the following sections, I will show that indeed there is a large price wedge in the electricity distribution market caused by precisely this problem. Namely, the marginal price of electricity distribution is too high, and the fixed price is too low. While this does not result in consumers paying more for electricity distribution, it distorts the market in a way that there is less electricity consumption than compared to an optimal scenario.

2.7 DNO pricing structure

As has been discussed previously, DNOs in Finland are regulated by their profits, and they can freely choose their pricing structures themselves. In many countries, including Finland, electricity distributors charge a fixed monthly fee along with a variable fee that changes according to consumption. This system makes sense for the market at hand, as in theory the variable fee can be set to equal marginal costs to ensure an efficient market and an optimal amount of electricity consumption. The fixed fee can then be set to recover the fixed costs associated with building and maintaining an electricity distribution network, and to ensure that DNOs remain profitable (Borenstein & Bushnell, 2021).

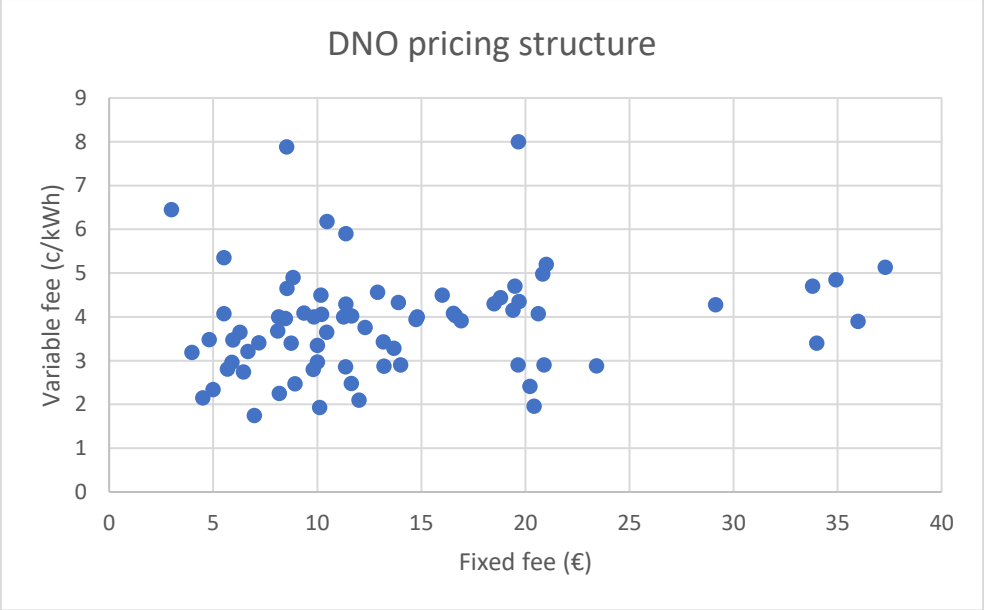
In Finland, even the fixed fee is not a fixed fee in a strict sense, as many DNOs offer a different fixed fee based on the size of the consumer's main fuse. That said, this can still be considered a fixed fee as a consumer cannot change the size of the main fuse in their house. In practice the only way a consumer can affect the size of their main fuse, and thus this fee, is by moving to a different house altogether.

Table 1 and Figure 1 below shows summary statistics on the fixed and variable fees of DNOs in Finland.

Table 1

Metric	Fixed fee (€)	Variable fee (c/kWh)
Mean	13.75	3.84
Median	11.38	3.93
Min	3.00	1.75
Max	37.30	8.00
Q1	8.48	2.92
Q2	11.38	3.93
Q3	18.73	4.35
Standard deviation	7.96	1.20

Figure 1



The fixed fee in Table 1 and Figure 1 is the fee DNOs charge for consumers of type L2 (see section 3.1 for a discussion on consumer types). This table and figure illustrate that DNOs have very different approaches to their pricing structures. This can be seen in the large differences in variable fees and fixed fees: some DNOs choose to charge higher fixed fees and lower variable fees while others choose the converse. Some of this is explainable by varying conditions: for instance, if a DNO operates in a sparsely populated area, it will have higher marginal costs from larger distribution distances, justifying a higher marginal cost.

That said, a large part of this variation is still unexplained by varying conditions, for instance due to geographic location. The DNOs have no monetary incentive to set their variable fees based on their marginal costs, and thus they can balance their fixed fees and marginal fees

however they see fit. This results in a price wedge, as any tariff structure where marginal fees are not equal to marginal costs lead to market distortions.

I have discussed the importance of tariff structures and later I will show that the tariff structures currently in use are not inefficient and lead to market distortions. What has not yet been discussed is how marginal costs are formed, and this will be discussed here.

Marginal cost of electricity distribution is mostly determined by distribution losses that occur during electricity distribution (Borenstein & Bushnell, 2021). The marginal cost can be further divided into two components: no-load losses and resistive losses. The no-load losses occur in transformers, and the resistive losses is energy that is lost to electrical resistance while distributing electricity and is dissipated as heat. According to Borenstein and Bushnell, the latter is the larger component of distribution losses.

For the purposes of this thesis, it is not necessary to distinguish between the two components of marginal costs. The data used here (see section 2.8.2 for more information on the distribution loss data) includes both sources of distribution losses. The assumption that is made in this thesis is that distribution losses are the sole component of the marginal cost a DNO faces, and this assumption will be discussed further in section 3.1.

2.8 Data

In order to perform the intended analysis on electricity distribution pricing, I will use three sets of data in this thesis. Firstly, I need data on the prices DNOs charge their customers. Secondly, I need data on the electricity losses DNOs face due to resistance with electricity distribution. Thirdly, I need data on the price of electricity in order to translate the electricity losses into monetary costs. For all of the data detailed below, I decided to use data for the year 2019. This is because data for 2019 was easily accessible, as enough time has passed to give the opportunity to collect and process the data. Also 2019 was recent enough that the data from then can provide relevant insights into todays market. While it would have been better to perform the analysis for multiple years, and over multiple Energy Authority monitoring cycles, this is not done in this thesis. This is because the distribution prices are relatively time invariant (Sahari, 2019), so there is not much variation from one year to the next. In addition, the DNO price data collection detailed in section 2.8.1 required manual work and this work would have needed to be replicated for each year studied.

2.8.1 Data on DNO pricing

The Finnish Energy Authority gathers data on the prices DNOs charge their customers. However, they do not publish the full data set. They create four typical consumers who live in different housing forms, from apartment buildings to detached houses. The Energy Authority assigns each of these example consumers an annual electricity consumption, and these range from 2 000 kWh/year to 20 000 kWh/year. In addition to these four type consumers, they also have two categories for farms and four categories for small and medium sized industrial plants. These are not of interest with regards to this thesis, so they will not be discussed further.

For these four type consumers, the Energy Authority publishes data on the average price DNOs charge their consumers. This is not very useful for this thesis, since optimizing consumers base their decision making on marginal price, not average price. Therefore, I resorted to manually searching and documenting the variable and fixed fees DNOs charge from their websites. This data is publicly available, and directly provides the marginal price data we are looking for. The pricing data used in this thesis is included in Appendix A.

2.8.2 Distribution loss data

As DNOs delivery electricity to consumer households, some of the electrical energy is lost to resistance. While there are other factors that affect the amount of energy lost, the most significant factor is distance: as the electricity is distributed across a larger distance, more electrical energy is lost to resistance. This is the main component of a DNOs marginal costs and for the purposes of this thesis it is assumed that a DNOs marginal costs consist solely of costs caused be loss of electrical energy to resistance. This is an assumption, but it is difficult to assess how strong of an assumption. Only DNOs accurately know their cost structure, and from the outside is difficult to assess this cost structure.

The FEA publishes data on the usage of electricity distribution networks on a DNO level. From this data, we can calculate the amount of electrical energy lost during distribution by calculating the difference between the total energy transferred into the network and total energy transferred out of the network.

The total energy transferred into the network is split into two components: electrical energy received from other networks and electrical energy received from customers. Similarly, the

total energy transferred out of the network is split into two components: electrical energy transferred to customers and electrical energy transferred to other networks. Combined these four categories describe all of the electrical energy in the network, and thus the difference between total inputs and total outputs sums to the electrical energy lost in distribution, measured in GWh. The distribution loss data used in this thesis is included in Appendix B.

2.8.3 Electricity price data

In order to translate the cost of distributing electricity, detailed in section 2.8.2, into monetary terms, we need data on the price of electricity. The FEA also publishes data on this. This data, like the data on DNO pricing the FEA publishes, is aggregated by the same type consumer categories. The data consists of three average monthly prices for each of these type consumers. The three different prices are the spot price, the price of a 1-year contract and the price of a 2-year contract.

For this thesis, I will use the spot prices for electricity. They reflect the marginal cost of electricity in the electricity market, and thus they are the relevant benchmark that should be used here.

In reality, DNOs might not use spot prices but they can have contracts with electricity producers that fix the prices they pay over a given period of time. The prices of these fixed electricity price contracts, such as yearly contracts, should be such that an optimizing consumer is indifferent between the prices. The yearly prices are simply adjusted to take into account the risk the electricity seller takes when they promise a fixed price for the period of time. Thus, it does not matter which price is used for the analysis and the results apply to all cases, but it is much easier to perform the analysis with the spot price.

I use the type customer L2 to as an example customer. This is a consumer who lives in a small house, with partially storing electric heating. This consumer type is chosen as it is the most relevant for this thesis (the reasoning will be explained in more detail in section 5.1). I average the electricity prices over the course of 2019 to get the yearly electricity price for a customer of type L2. This assumption and its implications will be discussed further in section 3.1. The electricity price data used in this thesis is included in Appendix C.

2.8.4 Marginal cost data

Now that we have the amount of electrical energy lost during distribution from section 2.8.2 and a unit price for electricity from section 2.8.3, we can combine this into the marginal cost a DNO faces. We multiply the two together to get the total cost that a DNO faces when distributing electricity to consumers. We then divide this amount by the electricity delivered to consumers, and we have the marginal cost of electricity distribution.

With these datasets, we are ready to calculate the optimal marginal price of electricity distribution and find out if the two-part tariff system currently in use is skewed towards overly high marginal prices.

Out of the 77 operational DNOs in Finland, the final dataset used in this thesis has data on 73 of them. The remaining four observations are removed from this analysis because of incomplete data. One DNO did not have distribution loss data available in FEAs dataset, one DNO did not have pricing data available, and two DNOs had neither of these pieces of data available for 2019.

Removing these DNOs from the analysis is not an issue, as the remaining 73 DNOs are plenty enough and geographically widespread enough to give a complete picture of the electricity distributors in Finland.

3 Assumptions and methodology

The goal of this thesis is to research whether the marginal price of electricity distribution is higher than the marginal cost of electricity distribution in Finland, and if so by what degree. Using the three datasets introduced in section 2.8, we can produce an estimate of what the marginal price of electricity distribution should be in order to facilitate an efficient market without distortions. This is what will be done in this section.

This section will detail how the empirical analysis on marginal costs of electricity distribution is conducted. First, I will discuss the assumptions used in the analysis. Second, I will detail how this marginal cost of electricity distribution is estimated in this paper. Third, I will discuss how the results about distribution marginal costs, prices charged by DNOs and the differences between the two will be presented.

3.1 Assumptions

The most important assumption in this thesis is that the marginal costs of DNOs consist solely of marginal costs that arise from the electrical energy lost during electricity distribution. While this is a heavy assumption, there are reasons why it is justified and not too unrealistic.

A fixed cost, as the name suggests, is a cost that does not change with the amount produced. When differentiating between what is a fixed cost and a marginal cost, the most important factor is time horizon. For instance, over a long enough time horizon, large investment decisions such as building factories or buying office spaces can be thought as non-fixed marginal costs. Conversely over short time horizons, costs such as staffing costs could be thought of as fixed costs instead of marginal costs.

The electricity market is a market where quantities sold differ largely within as small of a period as an hour. Thus, it makes sense to analyze how the market functions by using a short timeframe. In this short timeframe, the only component of marginal cost is the cost of the lost energy during distribution. Other costs are fixed over this short period of time, and thus they do not contribute to the firms pricing decision, or the consumers purchase decision (Kuosmanen, 2012).

This assumption has also been used in similar research conducted in the past. For example, Borenstein and Bushell make the same assumption in their 2021 paper, which assesses electricity and electricity distribution pricing the USA. The situation is slightly different in their case, as in the US electricity distributors are often vertically integrated with electricity producers, but this does not affect the validity of the assumption.

A consumer type is also assumed for this thesis. This is because some of the data provided by the FEA is divided into consumer types. One such dataset is the dataset on the price of electricity that the FEA provides.

In this data, the FEA provides a price for six types of consumers. Of these six, two concern farms and are not relevant for this thesis. Here is a summary table of the four remaining type consumers, that details the type of the consumer, its description and how much this type of consumer is assumed to consume electricity in a year (in kWh).

Table 2

Type	Description	Consumption
K1	Apartment building, no electric sauna, main fuse 1x25 A	2 000
K2	Small house, no electric heating, main fuse 3x25 A	5 000
L1	Small house, individual rooms electrically heated, main fuse 3x25 A	18 000
L2	Small house, partially stored electric heating, main fuse 3x25 A	20 000

I assume a consumer type of L2 for this thesis, and the price provided for this type of consumer is what is used in the following calculations. This is not a restrictive assumption, as the only effect this assumption has on the analysis is that it determines what electricity price the consumer is assumed to face. This electricity price assumption is necessary to calculate the monetary cost of the distribution losses a DNOs incurs.

The price difference between the consumer types, and thus the price difference caused by this assumption, is small. The consumer with the lowest electricity price if consumer type L2, and the consumer with the highest electricity price is K1. The average prices for these consumer types in 2019 was 6.32 and 8.48 c/kWh respectively (Energiavirasto, 2022). In section 4.4 I will conduct a sensitivity analysis on this consumer type assumption and show that this assumption does not meaningfully affect the results.

What the consumer type assumption does however affect is the effect of the price wedge on consumer choices. This is because the size of the price wedge is amplified by electricity consumption, and thus the absolute cost increase caused by the price wedge will be ten times greater for a customer of type L2 compared to a customer of type K1.

3.2 Calculating marginal cost

As explained in section 2.8.2, we can calculate the amount of energy lost during distribution (in GWh) as the difference between the energy that goes into a network and the energy that comes out of it. When we multiply the energy lost with the price of electricity, we get the cost of distribution for the DNO in question in Euros.

Once we have the total cost of distribution, we can divide this by the total amount of energy the DNO has delivered to its customers. This figure is included in the data the FEA provides, which is discussed in section 2.8.2.

Now we have the cost per kWh the DNO faces as a result of distributing energy, or the marginal cost of electricity distribution.

3.3 Presenting the findings

Since this analysis includes over 70 DNOs, showing the findings in a table is not very convenient. That is why I have produced figures, that show Finland separated into smaller areas according to the distribution network that operates in each area. Each area of the map is colored according to some variable. This variable is, depending on the case, the prices DNOs charge, the marginal costs faced by DNOs, or the difference of the two.

These maps are largely based on work that (Sahari, 2019) and (Putkiranta, 2022) have conducted.

4 Results

In this section we will go over the results of analyzing the pricing behavior of DNOs. First in section 4.1 I will discuss the prices charged by the DNOs, then in section 4.2 I will discuss the calculated variable costs, and then in section 4.3 I will discuss the price wedge which is the difference between marginal prices and the calculated variable costs.

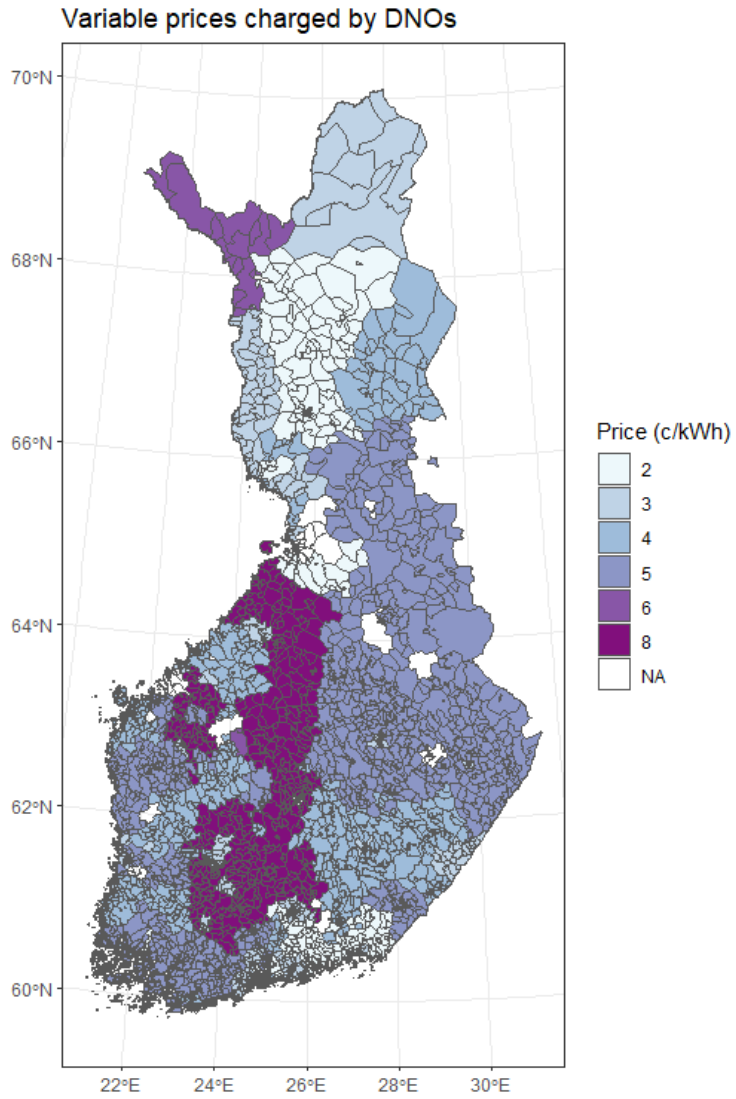
4.1 DNO pricing

As explained in section 2.8.1, this data is collected from the pricing information that DNOs publish on their websites. Below is table with summary statistics on the variable component of distribution pricing, and a figure showing how DNOs price the electricity distribution around Finland. It should be noted that this is only the variable component of distribution prices. This is because we are not interested in the fixed component of distribution pricing, as it does not affect the consumer decision on how much electricity to consume.

Table 3

Metric	Prices charged by DNOs (in c/kWh)
Mean	3.86
Median	3.94
Min	1.75
Max	8.00
Q1	2.96
Q2	3.94
Q3	4.35
Standard deviation	1.20

Figure 2

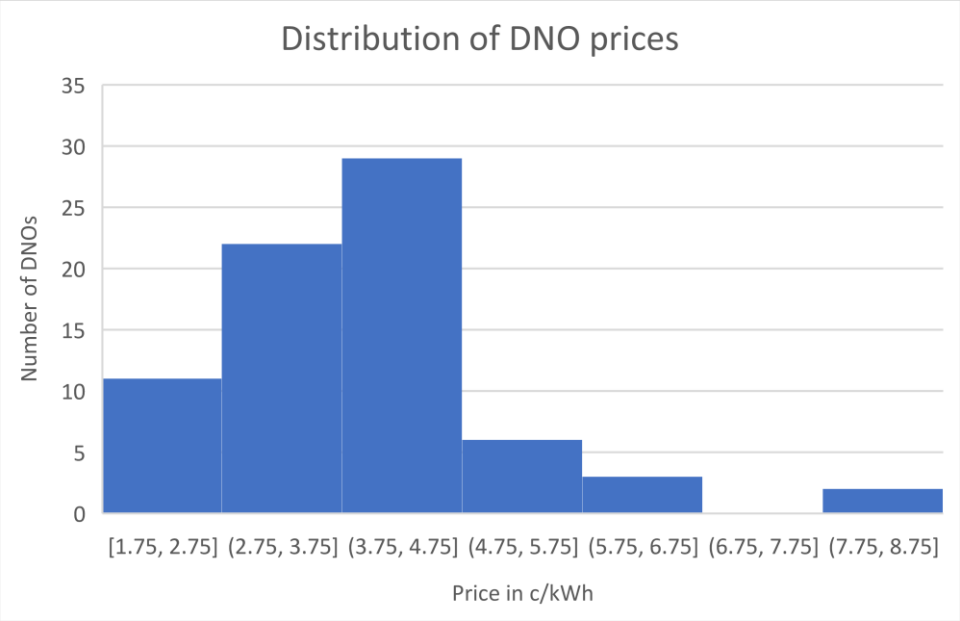


From Table 3, we see that the distribution price charged by DNOs range from 1.75 cents per kilowatt-hour (c/kWh) to 8 c/kWh and the mean price is 3.84 c/kWh. Figure 2 illustrates the

regional distribution in the prices. In this figure, the prices are rounded to the nearest whole number to keep the number of colors reasonable and distinguishable. We see that most of the prices are within the range of 3-5 c/kWh, but there is a large section of Finland between Hämeenlinna and Oulu where distribution prices are high.

It should be noted that the area of high distribution prices is one grid that is operated by a single distribution firm, Elenia Oy. It will not be done in this thesis, but one point of possible further research could be researching if there is a reason that Elenia sets its marginal price so high.

Figure 3



This point is further highlighted by Figure 3 above, which shows the distribution of prices. We see that a most DNOs set their marginal price between 2.75 and 4.75 c/kWh, and there are some outliers who set their price either below or above this norm.

This data alone does not tell us much, as it could be that the prices are high because the companies face high marginal costs. Next, we will be looking at the marginal costs DNOs face from electricity distribution.

4.2 Marginal costs of DNOs

In this section I will calculate the marginal cost that stem from electricity distribution. To do this I will use the distribution loss and electricity price data from sections 2.8.2.

I calculate the energy lost during electricity distribution simply as the difference between the amount of electrical energy that goes into the distribution and the amount of electrical energy that comes out of the network. The remaining energy has been converted to heat because of electrical resistance.

$$DL_n = IE_n^i + IE_n^e - \left(DE_n^i + DE_n^e\right)$$

(10)

Equation (10) describes the calculation of distribution losses. In equation (10), DL_n is the distribution losses of DNO n in GWh, IE_n^i is input energy going into grid n that comes from within the network (so from electric plants within the network, electricity that consumers provide to the network etc.) in GWh, IE_n^e is the input energy going into grid n that comes from external grids in GWh, DE_n^i is the delivered energy of grid n that is delivered internally (so to the customers of the DNO) in GWh, and DE_n^e is the delivered energy of grid n that is delivered to external grids in GWh. Below is a table summarizing the distribution losses of DNOs. The distribution losses indicated here is the amount of electrical energy lost during distribution as a percent of the total electrical energy distributed by the DNO.

Table 4

Metric	DNO distribution losses (%)
Mean	5.50 %
Median	3.64 %
Min	0.02 %
Max	28.68 %
Q1	2.79 %
Q2	3.64 %
Q3	5.04 %
Standard deviation	5.55 %

We see that there is very large deviation within the amount of energy lost during distribution. The DNO that loses the most energy during distribution loses over ten times the average amount. We also see that there is only a few DNOs with such high distribution losses. This can be seen in the large difference between the maximum and the third quartile, and also in the large difference between the mean and the median.

The next step is transforming the distribution losses into a monetary cost. This is simple, as we just need to multiply the distribution losses with the price of electricity, along with some unit conversions:

$$TC_n = 1\,000\,000 * DL_{DNO} * \frac{P_e}{100}$$

(11)

To get the total cost of electricity distribution for network n ($TC_n^{€}$) in euros, we need to convert the distribution losses into kWh and the price of electricity from c/kWh to €/kWh.

To convert this cost into the marginal cost faced by DNOs, we need to divide the total cost by the amount of electrical energy the DNO delivered to consumers, and again do some unit conversions.

$$MC_n = \frac{TC_n}{DE_n^i * 1\,000\,000} * 100$$

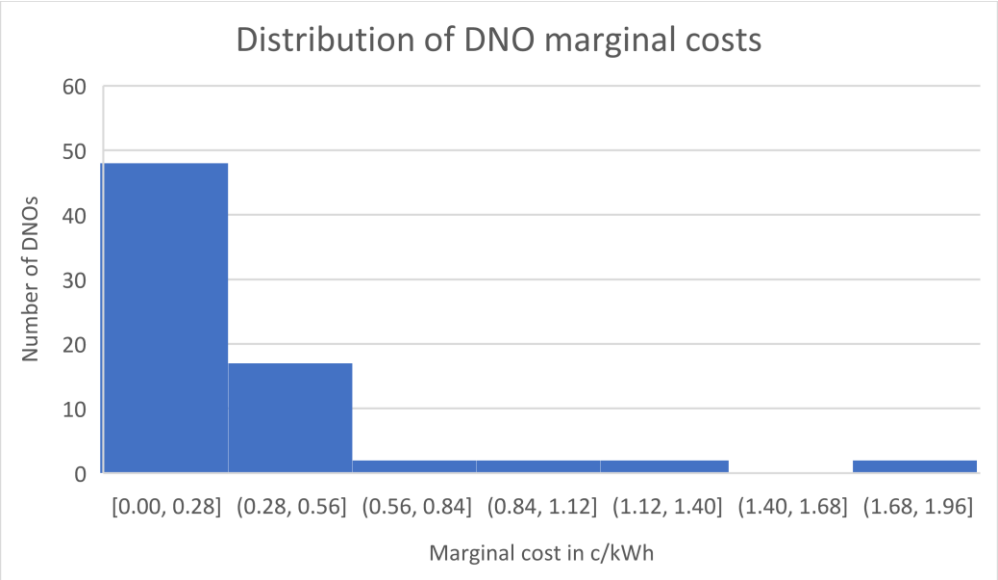
(12)

Now we have the marginal that arise from distributing electricity, calculated separately for each DNO. Below is a table with summary statistics of these marginal costs and histogram showing the distribution of marginal costs.

Table 5

Metric	DNO marginal costs (in c/kWh)
Mean	0.34
Median	0.23
Min	0.00
Max	1.81
Q1	0.18
Q2	0.23
Q3	0.32
Standard deviation	0.33

Figure 4



We see that the vast mast majority of DNOs have very low distribution costs that fall in the range of 0-0.28 c/kWh. Some DNOs fall into the next category of 0.28-0.56 c/kWh, and the rest are scattered into the higher price brackets. This distribution makes sense since there are many sparsely populated areas in Finland. In these areas the distribution distances are long, which increases the marginal cost of delivering electricity.

Figure 5

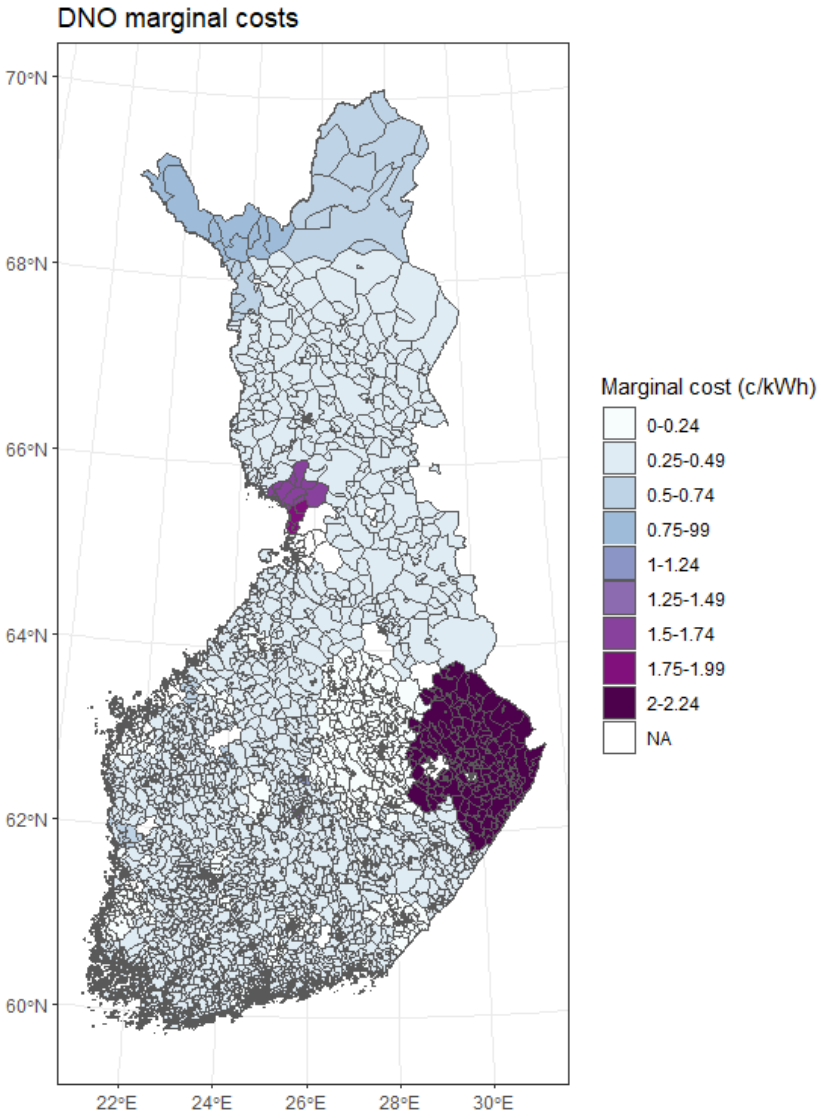


Figure 5 above visualizes how the marginal costs of DNOs vary regionally. The marginal costs have been grouped into categories of size 0.25. We see that the highest costs are in eastern Finland. This is a region where PKS Sähkösiirto Oy is the DNO who operates the network, and they have the highest distribution loss percentage of 28.7% in all of Finland. The region between Oulu and Kemi is another area with larger costs. The smaller, more expensive area is operated by Iin Energia Oy, and the slightly larger less expensive area is operated by Rantakairan Sähkö Oy. They have the second and third largest distribution loss ratios in Finland, at 27.5% and 21.0% respectively. It can also be seen that distribution costs are slightly higher in northern Finland compared to the rest of the country. For detailed numbers about the marginal costs of individual DNOs, see Appendix D.

4.3 Price wedge

Now we can calculate the difference between the variable prices charged by DNOs and the marginal costs of DNOs, or the price wedge. The price wedge is described by the following equation.

$$PW_n = P_n - MC_n$$

(13)

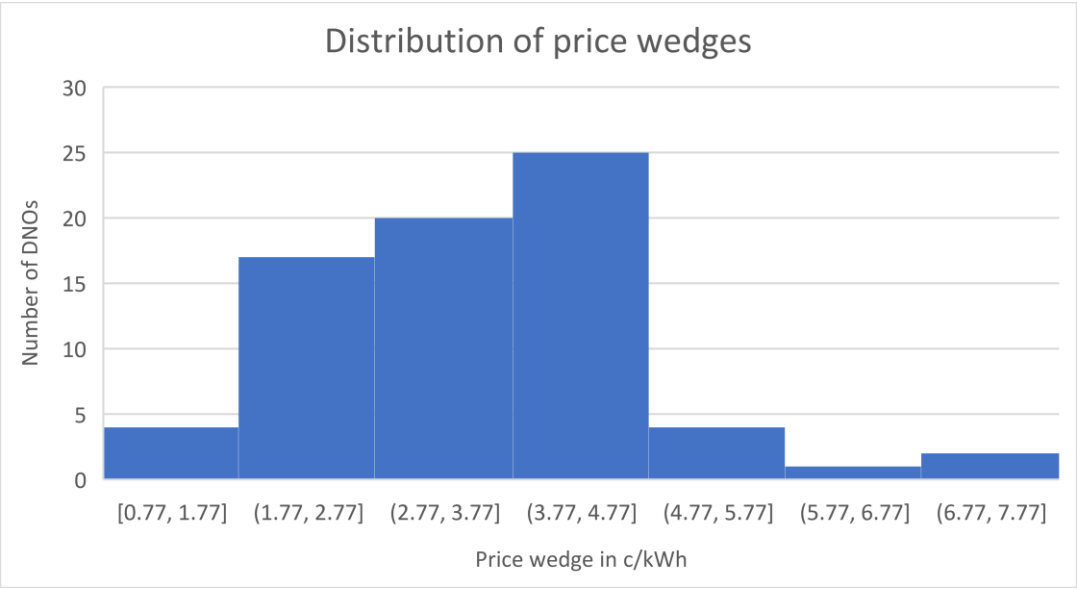
Where PW_n is the market distorting price wedge for DNO n, P_n is the variable price charged by DNO n, and MC_n is the marginal cost of DNO n that we calculated earlier.

Below is a table of summary statistics and the distribution of the price wedge.

Table 6

Metric	Price wedge (in c/kWh)
Mean	3.52
Median	3.60
Min	0.77
Max	7.72
Q1	2.64
Q2	3.60
Q3	4.11
Standard deviation	1.240

Figure 6



We can see that the mean price wedge is 3.52 c/kWh, and the price wedge ranges from 0.7 to 7.72 c/kWh. From Figure 6, we see that the distribution is fairly similar to the distribution of prices in Figure 3 (section 5.1). Most of the DNOs have a price wedge that is between 1.77 and 4.77 c/kWh. A handful of DNOs have a lower price wedge, and there is a thin right-tail of DNOs that have increasing prices wedges all the way up to the largest value of 7.77 c/kWh.

Figure 7

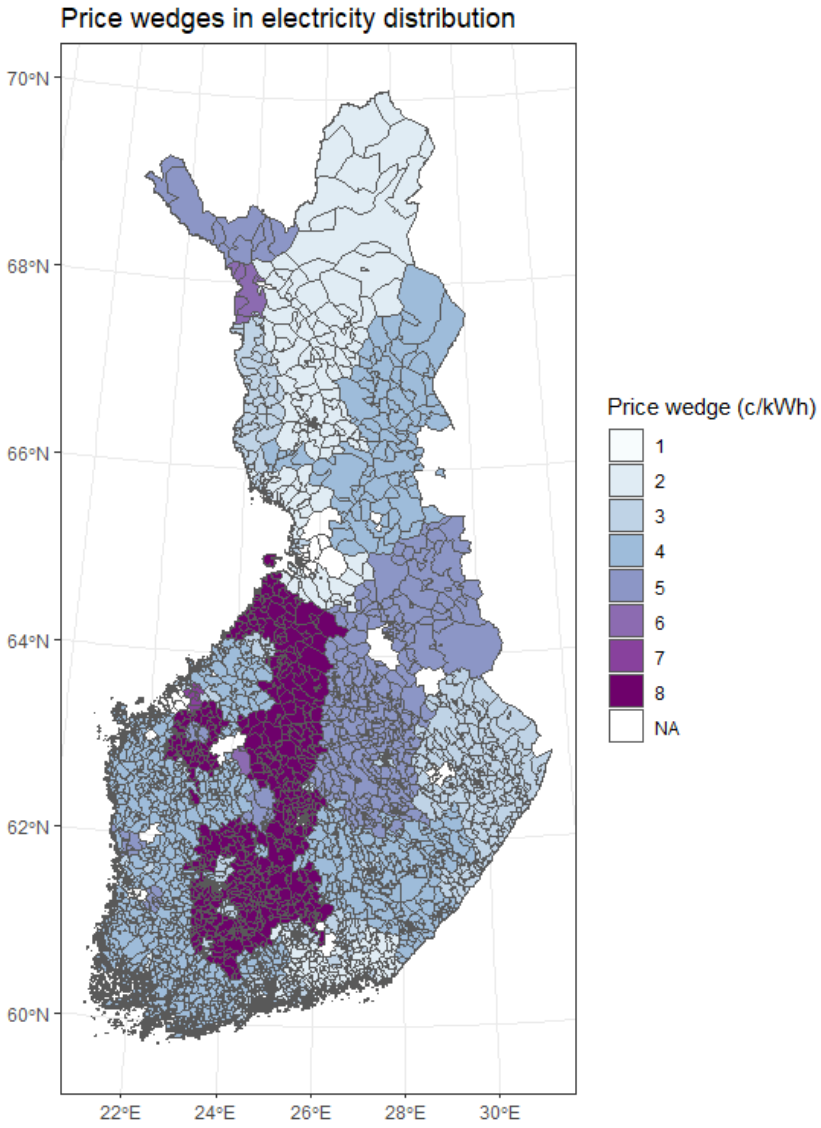


Figure 7 shows the variation in price wedges by region. Similarly to Figure 2 (section 5.1), the price wedge has been rounded to the nearest whole number to keep the number of categories reasonable. When we compare this figure to figure 3, we can see that the largest price wedges are in the same are where the prices are highest, so from Hämeenlinna to Oulu. This demonstrates that the high prices in this area are not justified by marginal costs, and this

creates a price wedge in the market causing inefficiency. For details on the price wedges of individual DNOs, see Appendix D.

As noted in section 4.1, the area with the highest price wedge is an area where a single DNO, Elenia Oy, operates. Elenia Oy is the second largest distribution network in Finland, after Caruna Oy, if measured by amount of electrical energy distributed to customers.

High marginal price can also be found in eastern and northern Finland. As seen from figure 3, these areas also have high marginal prices. However, these high prices can be justified to some extent because of high marginal costs in these areas. As a result, the price wedge falls broadly in line with the rest of Finland.

Even ignoring the areas with large price wedges and looking at the mean price wedge in Finland, this figure is 3.52 c/kWh. This is a very significant amount, considering that the average spot electricity price for consumers of type L2 in 2019 was 6.32 c/kWh (Appendix C). Since the average variable price charged by DNOs is 3.86 c/kWh, this means that the current total marginal (TMP_c) price consumers face is the sum of the electricity price (P_e), the variable price of distribution (VP_d), and the tax (τ):

$$TMP_c = P_e + VP_d + \tau = 6.32 + 3.86 + 2.79 = 12.97\ c/kWh$$

(14)

The average market price in an efficient market would be lower by the amount of the average price wedge (P_w), so 3.52 c/kWh. This mean that in an efficient market, the total marginal price for electricity (TMP_e) would be:

$$TMP_e = TMP_c - P_w = 12.97 - 3.52 = 9.45\ c/kWh$$

(15)

$$\%\Delta = \frac{12.97}{9.45} - 1 = 37.3\%$$

(16)

These calculations show that in an efficient market, the average marginal price consumers face should have been 9.45 c/kWh in 2019, and the actual market price was 37.3% too high. This is a very significant price wedge.

At the time of writing, the price of electricity has increased significantly due to exogenous, and presumably temporary, reasons. During October of 2022, the spot price of electricity for the consumer type K2 was 14.95 c/kWh and for November it was 32.05 c/kWh (Energiavirasto, 2022). Even for the inflated electricity price for November 2022, the price wedge still causes an 10% increase in prices, which is still a very noticeable increase.

It should be emphasized that this market distortion does not directly translate into welfare loss for consumers. This is because even if DNOs would adjust their prices to match their marginal costs of distributions, they would raise the fixed fees they charge consumers in order to compensate for the loss in revenue. This is because the DNOs still need to get enough revenue to maintain the distribution networks the same way as they do now. This is because in this thesis it is assumed that the monopoly profits of DNOs are correctly regulated, and thus currently DNOs make just enough profit to enable their operation.

In other words, as a whole consumers would still pay exactly the same amount and DNOs would still earn the exact same amount. What this would do is it would increase the options consumers have by effectively subsidizing everything that uses electricity, such as electric vehicles and electric heating. This is where the market inefficiency stems from, and incentivizing DNOs to have pricing structures that enable an efficient market outcome would fox this inefficiency.

4.4 Sensitivity analysis of the customer type assumption

This thesis has operated on the assumption that consumers are of type L2, as explained in section 3.1. In this section, it will be shown that this assumption is not restrictive, and that the results of this analysis apply more generally than only to consumers of type L2.

The assumption of the consumer type was made because the FEA collects and publishes data aggregated into these consumer types. The type L2 was chosen because this type of consumer has electric heating in their home, and as such has a relatively high electricity consumption. Thus, this is the most relevant consumer type out of the selection that the FEA uses, and this is the reason that so far this thesis has assumed this particular consumer type.

The only way the consumer type assumption affects the analysis is by the electricity price they face and the amount of electricity they consume. The electricity consumption only affects section 5 of the analysis done in this thesis, as it does not affect marginal prices and marginal costs.

Largest differences come from areas with high distribution losses and thus high marginal costs. In these areas small changes in price have the largest effect.

Figure 8

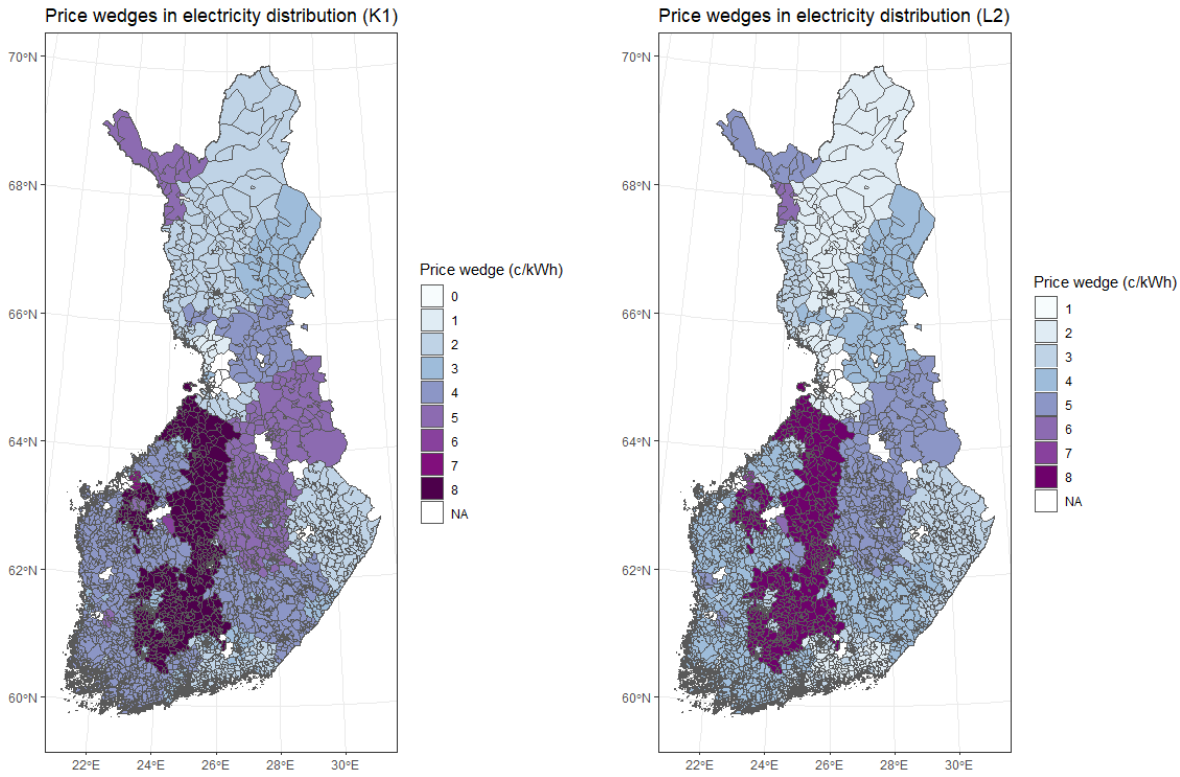


Figure 8 above shows a comparison between the price wedges caused by DNO tariff structures. On the right we can see the L2 consumer type used throughout this thesis, and on the left is the price wedge for consumers of type K1. The figure on the right is exactly the same as Figure 7 in section 4.3, but it is shown here to easily compare the two customer types.

The K1 consumer type is the type with the smallest electricity consumption, as can be seen from Table 2. A consumer of type K1 lives in an apartment building without a sauna, the consumer 2 000 kWh per year (compared to the 20 000 kWh per year a consumer of type L2

uses), and they have a smaller main fuse of 1x25 A than the rest of the types. As such, consumers of type K1 have the highest electricity costs (Energiavirasto, 2022).

The size of the price wedge between consumers of L2 and consumers of other types must be at most as much as the difference between consumers of type L2 and type K1. In other words, the price wedge is the smallest with consumers of type K1, and largest with consumers of type L2. This is because the marginal prices charged by DNOs can be justified with higher electricity prices, as this raises marginal costs for DNOs.

We can see from Figure 8 that the price wedges are very similar between customers of type L2 and K1. This can be seen even more clearly from Figure 9 below.

Figure 9

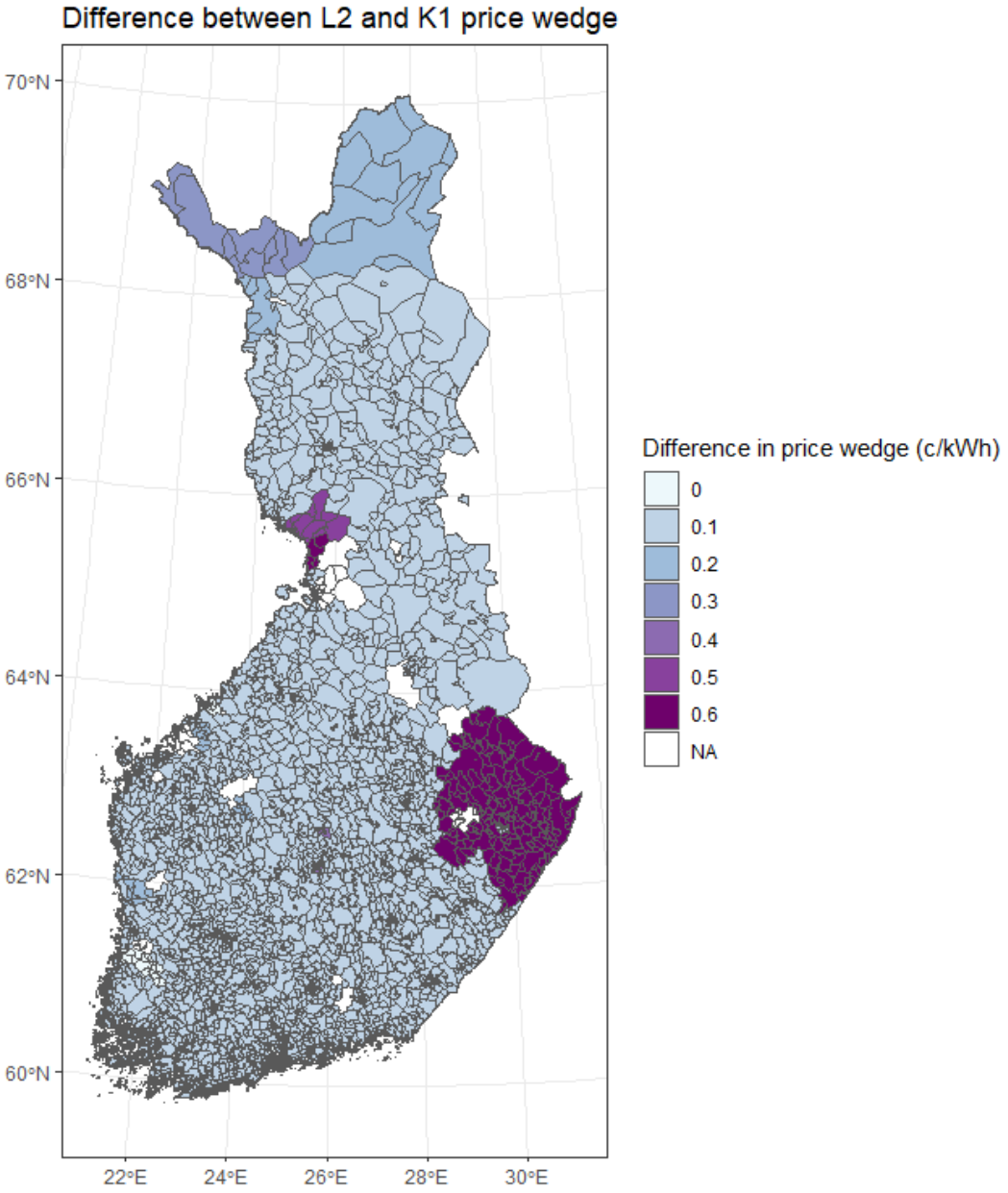


Figure 9 shows us the difference between the price wedges calculated for consumers of types L2 and K1. From Figure 9 we can see that throughout most of Finland, the difference between the two customer types is not large. We can see that the differences are the largest in areas where distribution losses are the highest, so in eastern Finland and between Oulu and Kemi. This is expected, as the small changes in price due to the change in consumer type is amplified by the large distribution losses. The result is that marginal costs in areas with large distribution losses are more sensitive to this assumption.

That said, the price wedge in eastern Finland, where this amplification is the strongest, is still 2.27 c/kWh with the K1 customer type, which is still quite significant. From this we can conclude that the assumption of consumer type does not meaningfully restrict the result of this analysis, as mostly the differences caused by this assumption are small. Furthermore, even in regions where the assumption results in large differences, there is still a significant price wedge.

5 Effect of the price wedge on consumer costs

In section 4, it was shown that a price wedge exists in the electricity distribution market, and that this wedge prevents the market from operating efficiently. In this section, I will discuss how the price wedge resulting from DNO tariff structures affects the costs of consumers who use electricity intensive products. In particular, this chapter will discuss two examples: electric heating of houses, and electric vehicles.

5.1 Electric heating

The consumers who can choose what type of heating system their house has are consumers who live in detached houses. This is because of two reasons. Firstly, apartment buildings and row houses are typically built by construction companies who then sell the houses to households, and thus the households are not part of the decision-making process for their homes' heating system. This is in contrast to detached house owners, who often build their houses themselves. Owners of detached houses often act as developers in the building process, where they can influence decisions such as what heating system the house uses. (Sahari, 2019)

Secondly, owners of detached houses can (to some extent) retroactively change the heating system once the house is built. For example, in a detached house with central heating[1] that uses oil as an energy source, the owner can choose to switch their oil kettle for an electric one. This is not possible in apartments or row houses, where the heating of one household is integrated into the heating of the whole building.

[1] Central heating is a common heating method in Finland, where water is heated in a central location using some fuel (e.g. oil or electricity), and then distributed around the house to heat the house through radiators or in-floor heating

Because consumers living in detached houses have better control over the heating systems their houses use, their incentives will be affected the most by market inefficiencies, and this is why this section will focus on them. In Finland, detached single-family houses account for 41% of residential houses (Sahari, 2019). This illustrates that a very significant share of the Finnish population lives in detached houses, and market inefficiencies can affect the incentives and choices of a large proportion of Finnish households.

According to a study done by Adato Energia (2013), an average 4-person household living in a detached house that is heated with electricity consumes 19 600 kWh of electricity per year. Of this total, 49% or 9 600 kWh is spent on heating. Using the average price wedge calculated in section 4.3, we can calculate the effect of the price wedge on the marginal costs of an average consumer who lives in an electrically heated detached house:

$$\frac{3.52}{100} * 19\,600 = 689.92€$$

(17)

Of the total electricity consumption, 9 600 kWh is spent on heating. Thus, we can calculate the effect of the price wedge on the marginal costs of electric heating:

$$\frac{3.52}{100} * 9\,600 = 337.92€$$

(18)

Equations (17) and (18) show us the additional marginal costs that consumers who live in electrically heated detached houses pay. This cost comes from the price wedge and market distortion that is caused by DNO tariff structures. Equation (18) is the more interesting of the two, as electric heating has many close substitutes. Increased marginal costs can affect consumer decision, and result in the over-consumption of carbon intensive products such as oil-kettle heating in detached houses. Equation (18) tells us that in an efficient market, the average household with electric heating should pay 337.92€ less per year for their heating.

While the result of equation (17) is still interesting, it is not as interesting as equation (18). This is because the electricity consumption of a household that does not go into heating is used mostly in electrical machines, such as refrigerators, dishwashers, and laundry machines

(Adato Energia, 2013). For these applications there are not close substitutes, and thus this increase in marginal cost will not affect purchase decisions as much.

The additional marginal cost consumers pay is significant, and it is clear that the current DNO tariff structure results in electric heating being a less appealing choice than it would be in an efficient market. This makes carbon intensive heating options like oil-based central heating more appealing in comparison. However, it is unclear how much this would affect consumer incentives, and thus the amount of electric heating in Finland. This is beyond the scope of this thesis, but a point of further research would be to model consumer behavior considering this price wedge. For example, this could be done by looking at price elasticities of consumers for heating options.

5.2 Electric vehicles

We can perform a similar calculation as in the previous section for electric vehicles, to see the effect of the price wedge on the marginal costs of electric vehicle ownership. According to an article by Virta (2019), the electricity consumption of electric vehicle (EV) can vary by model and by season, but on average an EV in Finland consumes 0.2 kWh/km and on average a Finn drives 16 800 per year. This means that the average annual electricity consumption for an EV is:

$$0.2 * 16\,800 = \ 3\,360\ kWh \tag{19}$$

Using this, we can calculate the effect this price wedge has on marginal costs:

$$\frac{3.52}{100} * 3\,360 = 118.27€ \tag{20}$$

From equation (20), we see that the average yearly marginal cost of using an EV is 118.27€ than it would be in an efficient market. The same discussion from electric heating applies here: EVs have close carbon-intensive substitutes, and inflated marginal costs for EV use makes these substitutes more appealing. As was the case with electric heating, it is hard to say how much this would affect consumer choices, and this is a point of further research.

6 Conclusion

As has been discussed in this thesis, the current regulation concerning electricity distribution ensures that distribution network operators do not make excessive profits, and this is an important objective in of itself. However, the current regulation does not monitor or mandate DNO pricing strategies, and this leaves the possibility for market efficiencies to rise.

As this thesis has shown, this is indeed the case and there is a significant difference between the prices DNOs charge their customers and the marginal costs that arise from electricity distribution. At best the price wedge formed by this difference is 0.77 c/kWh, and at worst it is 7.72 c/kWh. The average price wedge in 2019 was 3.52 c/kWh, which resulted in a 30.3% increase in total electricity prices for the average consumer.

It must be emphasized that this does not directly translate into welfare loss for the consumer. The reason for this is that if marginal prices were corrected to the level of marginal costs, DNOs would raise fixed prices to compensate for this loss in revenue. However, this does affect consumer decision making, as this price wedge makes electricity consumption much more expensive.

This problem arises from the fact that current regulation does not say anything about the pricing models DNOs use, but only the amount of profits DNOs are allowed to make is regulated. Thus, DNOs have no incentive to use a pricing mechanism that results in an efficient market. This results in inefficiencies in the electricity distribution market and fixing this inefficiency with regulation would improve net welfare.

In this thesis, I have also shown the effect this price wedge has on owners of electrically heated houses and electric vehicles. On average, the marginal costs of electrically heating a house and driving an electric vehicle are inflated by 337.92€ and 118.27€ respectively per year. This is an issue, as electric heating and electric vehicles have close carbon-intensive substitutes and these inflated marginal costs caused by the market inefficiency make these substitutes more appealing.

Reforming regulation would be desirable not only to facilitate an efficient electricity distribution market, but also to effectively subsidize these eco-friendly forms of heating and transportation. Removing this price wedge from the electricity distribution market would

lower consumer prices significantly: by around 9% with the electricity prices of November 2022, and by 27% with 2019 electricity prices.

With cheaper marginal prices for electricity, consumers would have more incentive to replace carbon intensive products like combustion engine vehicles and oil heating with electric options, such as electric vehicles and electric heating. In this thesis, I have calculated the monetary increase in marginal costs that this market inefficiency causes. A point of further research would be to examine how this increase in marginal costs affects consumer behavior. This could for instance be done by researching price elasticities of consumers, and thus estimating the magnitude of the effect of this market inefficiency on consumer choices.

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Appendix A: DNO pricing data

Here is the pricing data collected from the DNOs websites used in this thesis. The fixed fee is fee the company charges for a 3 x 25 ampere main fuse. The prices include VAT but not the electricity tax, which is part of the price of electricity, not the price of electricity distribution. The source of this data is DNO websites.

Distribution company	Fixed fee eur/month	Variable fee c/kWh
Äänekosken Energia Oy	10.46	3.65
Alajärven Sähkö Oy	3	6.45
Caruna Espoo Oy	5.9	2.96
Caruna Oy	12.9	4.56
Elenia Verkko Oyj	19.67	8
Enontekiön Sähkö Oy	11.38	5.9
ESE-Verkko Oy	8.75	3.4
Esse Elektro-Kraft Ab	8.524166667	7.88
Forssan Verkkopalvelut Oy	13.69	3.28
Haminan Energia Oy	19.65	2.9
Haukiputaan Sähköosuuskunta	4.8125	3.48
Helen Sähköverkko Oy	5.51	4.07
Herrfors Nät-Verkko Oy Ab	13.2	2.87
Iin Energia Oy	6.29	3.65
Imatran Seudun Sähkönsiirto Oy	19.41	4.15
Jakobstads Energiverk	-	-
Järvi-Suomen Energia Oy	29.14	4.28
Jeppo Kraft Andelslag	11.27	4
Alva Sähköverkko Oy	10.11	1.93
Jylhän Sähköosuuskunta	8.833333333	4.9
Kemin Energia ja Vesi Oy	8.1025	3.68
Keminmaan Energia Oy	8.93	2.47
Keravan Energia Oy	4.5	2.15
Keuruun Sähkö Oy	19.5	4.7
Koillis-Lapin Sähkö Oy	16.92	3.91
Koillis-Satakunnan Sähkö Oy	16.63	4.03
Kokemäen Sähkö Oy	20.83	4.98
Kokkolan Energiaverkot Oy	8.4666	3.96
Köyliön-Säkylän Sähkö Oy	20.62	4.07
Kronoby Elverk Ab	10.18333333	4.5
KSS Verkko Oy	12.3	3.76
Kuopion Sähköverkko Oy	7.2	3.41
Kuoreveden Sähkö Oy	35.99	3.9
Kymenlaakson Sähköverkko Oy	20.22	2.41
Lankosken Sähkö Oy	21	5.2
Lappeenrannan Energiaverkot Oy	8.54	4.65
Lehtimäen Sähkö Oy	16	4.5

Leppäkosken Sähkö Oy	19.7	4.35
LE-Sähköverkko Oy	5.95	3.47
Kajave Oy	37.3	5.13
Muonion Sähköosuuskunta	10.465	6.18
Naantalin Energia Oy	9.84	4
Nivos Energia Oy	16.55	4.08
Nurmijärven Sähköverkko Oy	10	2.97
Nykarleby Kraftverk Ab	-	-
Oulun Energia Sähköverkko Oy	-	-
Oulun Seudun Sähkö Verkkopalvelut Oy	11.63	2.48
Okun Energia Oy	5.679166667	2.81
Paneliankosken Voima Oy	13.9	4.33
Parikkalan Valo Oy	34	3.4
PKS Sähkösiirto Oy	33.8	4.7
Pori Energia Sähköverkot Oy	13.17	3.43
Porvoon Sähköverkko Oy	14	2.9
Raahen Energia Oy	5.511666667	5.35
Rantakairan Sähkö Oy	11.36666667	2.86
Raseborgs Energi Ab – Raaseporin Energia Oy	14.74	3.94
Rauman Energia Sähköverkko Oy	9.8	2.8
Rovakaira Oy	20.42	1.96
Rovaniemen Verkko Oy	8.18	2.25
Sallila Sähkönsiirto Oy	18.5	4.3
Savon Voima Verkko Oy	34.92	4.85
Seiverkot Oy	6.67	3.21
Sipoon Energia Oy	12	2.1
Tampereen Sähköverkko Oy	3.98	3.1868
Tenergia Oy	10.2075	4.06
Tornion Energia Oy	6.45	2.74
TLS Verkko Oy	20.9	2.9
Tunturiverkko Oy	23.41666667	2.88
Turku Energia Sähköverkot Oy	6.98	1.75
Vaasan Sähköverkko Oy	9.36	4.09
Vakka-Suomen Voima Oy	14.8	4
Valkeakosken Energia Oy	10	3.35
Vantaan Energia Sähköverkot Oy	5	2.34
Vatajankosken Sähköverkko Oy	18.8	4.44
Verkko Korpela Oy	8.15	4
Vetelin Energia Oy	11.375	4.29
Vimpelin Voima Oy	11.66	4.02

Appendix B: DNO distribution loss data

The data used to calculate distribution losses of DNOs. This data is from (Energiavirasto, 2022).

Company name	Electrical energy distributed to customers, GWh	Electrical energy received from customers, GWh	Electrical energy distributed to other networks, GWh	Electrical energy received from other networks, GWh
Alajärven Sähkö Oy	111.919	3.782	0.07	112.283
Alva Sähköverkko Oy	664.847	376.056	260.108	671.013
Caruna Espoo Oy	2993.638	872.846	0.262	2204.527
Caruna Oy	7376.998	3404.415	4170.957	8491.529
Elenia Verkko Oyj	6091.718	1614.337	1346.946	6097.757
Enontekiön Sähkö Oy	29.195	0.007	0.609	33.754
ESE-Verkko Oy	323.951	139.771	0.805	193.7
Esse Elektro-Kraft Ab	51.935	13.075	1.265	43.929
Forssan Verkkopalvelut Oy	213.791	37.567	0	182.298
Haminan Energia Oy	156.868	36.843	0	124.403
Haukiputaan Sähköosuuskunta	147.1	0.105	0	151.791
Helen Sähköverkko Oy	4383.122	4123.486	819.502	1178.498
Herrfors Nät-Verkko Oy Ab	679.787	502.046	440.279	641.074
Iin Energia Oy	68.596	16.964	0	70.514
Imatran Seudun Sähkönsiirto Oy	254.24	0.241	0	263.4
Jeppo Kraft Andelslag	19.705	0	0	20.249
Jylhän Sähköosuuskunta	73.815	1.331	0	75.874
Järvi-Suomen Energia Oy	1068.777	89.761	12.397	1031.373
Kajave Oy	743.691	67.266	8.032	717.028
Kemin Energia ja Vesi Oy	165.7	0.055	0	171.6
Keminmaan Energia Oy	72.015	0.032	0	76.013
Keravan Energia Oy	284.493	85.184	0	206.413
Keuruun Sähkö Oy	104.92	5.094	0	102.402
Koillis-Lapin Sähkö Oy	174.821	10.379	1.17	176.38
Koillis-Satakunnan Sähkö Oy	170.909	33.131	0	146.266
Kokemäen Sähkö Oy	78.474	0.059	0	81.54
Kokkolan Energiaverkot Oy	471.492	78.718	7.758	409.987
Kronoby Elverk Ab	47.1	0	0	48.8
KSS Verkko Oy	611.811	137.923	115.635	615.42
Kuopion Sähköverkko Oy	610.265	345.823	104.304	388.035
Kuoreveden Sähkö Oy	32.055	0.025	0	33.54
Kymenlaakson Sähköverkko Oy	1275.187	89.466	301.615	1541.675
Köyliön-Säkylän Sähkö Oy	200.465	0.087	52.298	256.678

Lammaisten Energia Oy	132.01	0.111	272.198	408.713
Lankosken Sähkö Oy	23.676	1.678	0.005	24.123
Lappeenrannan Energiaverkot Oy	737.174	0.248	0	754.433
Lehtimäen Sähkö Oy	16.901	0.014	0	18.341
Leppäkosken Sähkö Oy	373.042	6.8	0	380.4
LE-Sähköverkko Oy	1196.714	362.562	51.648	923.066
Muonion Sähköosuuskunta	44.186	4.18	0	44.003
Naantalin Energia Oy	127.504	0.082	0	131.9
Nivos Energia Oy	367.581	1.032	113.447	489.143
Nurmijärven Sähköverkko Oy	420.2	0.41	0	442.517
Nykarleby Kraftverk Ab	79.275	14.669	20.74	104.002
Oulun Energia Siirto ja Jakelu Oy	1310.337	803.406	10.765	562.021
Oulun Seudun Sähkö Verkkopalvelut Oy	472.491	22.763	0.004	466.312
Outokummun Energia Oy	151.25	0.038	0	153.78
Paneliankosken Voima Oy	339.196	3.035	0	341.954
Parikkalan Valo Oy	135.531	7.662	0	132.802
PKS Sähkösiirto Oy	1044.924	310.955	2.781	1036.418
Pori Energia Sähköverkot Oy	970.698	579.95	131.504	555.154
Porvoon Sähköverkko Oy	438.061	3.07	1482.279	1943.584
Raahen Energia Oy	103.131	20.888	20.865	103.131
Rantakairan Sähkö Oy	41.745	56	46.911	41.412
Raseborgs Energi Ab – Raaseporin Energia Oy	85.2	14.409	0	75.084
Rauman Energia Sähköverkko Oy	293.193	0.13	0	300.678
Rovakaira Oy	746.02	14.655	0.404	770.954
Rovaniemen Verkko Oy	322.878	136.118	0	198.134
Sallila Sähkönsiirto Oy	342.185	12.248	0	342.587
Savon Voima Verkko Oy	1752.335	270.55	37.3	1563.5
Seiverkot Oy	436.722	12.651	0	435.597
Sipoon Energia Oy	282.816	0.143	0	293.397
Tampereen Sähköverkko Oy	1901.061	587.461	34.008	1400.152
Tenergia Oy	41.097	42.888	0	0
Tornion Energia Oy	165.389	0.087	0	172.125
TLS Verkko Oy	224.906	126.199	0.947	112.325
Tunturiverkko Oy	166.855	4.244	2.489	179.669
Turku Energia Sähköverkot Oy	1500.534	0.778	677.751	2221.415
Vaasan Sähköverkko Oy	978.516	37.703	0	972.471
Vakka-Suomen Voima Oy	423.422	1.16	0	435.652
Valkeakosken Energia Oy	184.582	0.073	0	190.823

Vantaan Energia Sähköverkot Oy	1899.775	496.274	0.244	1445.771
Vatajankosken Sähköverkko Oy	267.77	98.264	61.898	244.358
Verkko Korpela Oy	334.201	12.855	0.015	340.089
Vetelin Energia Oy	27.867	2.773	0	25.762
Vimpelin Voima Oy	29.068	0.018	0.214	30.519
Äänekosken Energia Oy	115.442	0.058	62.58	197.986

Appendix C: electricity price data

The electricity price data used in this thesis, separated in to customer groups. The data is from (Energiavirasto, 2022)

c/kWh	K1	K2	L1	L2	M1	M2
1/1/2019	9.05	7.81	7.40	7.10	7.40	7.17
½/2019	8.11	6.95	6.74	6.44	6.87	6.65
1/3/2019	8.46	7.15	6.70	6.47	6.90	6.70
¼/2019	8.48	7.16	6.43	6.20	6.90	6.70
1/5/2019	8.48	7.16	6.43	6.20	6.90	6.69
1/6/2019	8.50	7.19	6.46	6.23	6.93	6.71
1/7/2019	8.44	7.10	6.33	6.10	6.85	6.59
1/8/2019	8.46	7.12	6.41	6.18	6.88	6.63
1/9/2019	8.46	7.12	6.41	6.18	6.88	6.62
1/10/2019	8.43	7.10	6.46	6.23	6.85	6.62
1/11/2019	8.45	7.11	6.47	6.23	6.86	6.62
Average	8.48	7.18	6.57	6.32	6.93	6.70

Appendix D: marginal price, marginal cost, and price wedge

Sähköyhtiö	Marginal price c/kWh	L2 marginal cost c/kWh	Price wedge c/kWh
Äänekosken Energia Oy	3.65	1.096772	2.55
Alajärven Sähkö Oy	6.45	0.230305	6.22
Caruna Espoo Oy	2.96	0.176327	2.78
Caruna Oy	4.56	0.298304	4.26
Elenia Verkko Oyj	8	0.283844	7.72
Enontekiön Sähkö Oy	5.9	0.857098	5.04
ESE-Verkko Oy	3.4	0.170122	3.23
Esse Elektro-Kraft Ab	7.88	0.463184	7.42
Forssan Verkkopalvelut Oy	3.28	0.179663	3.10
Haminan Energia Oy	2.9	0.176488	2.72
Haukiputaan Sähköosuuskunta	3.48	0.206177	3.27
Helen Sähköverkko Oy	4.07	0.143351	3.93
Herrfors Nät-Verkko Oy Ab	2.87	0.21446	2.66

Iin Energia Oy	3.65	1.740693	1.91
Imatran Seudun Sähkönsiirto Oy	4.15	0.233832	3.92
Järvi-Suomen Energia Oy	4.28	0.236435	4.04
Jeppo Kraft Andelslag	4	0.17458	3.83
Alva Sähköverkko Oy	1.93	1.161493	0.77
Jylhän Sähköosuuskunta	4.9	0.290421	4.61
Kemin Energia ja Vesi Oy	3.68	0.227265	3.45
Keminmaan Energia Oy	2.47	0.353879	2.12
Keravan Energia Oy	2.15	0.157908	1.99
Keuruun Sähkö Oy	4.7	0.15526	4.54
Koillis-Lapin Sähkö Oy	3.91	0.389506	3.52
Koillis-Satakunnan Sähkö Oy	4.03	0.314061	3.72
Kokemäen Sähkö Oy	4.98	0.251824	4.73
Kokkolan Energiaverkot Oy	3.96	0.126812	3.83
Köyliön-Säkylän Sähkö Oy	4.07	0.126244	3.94
Kronoby Elverk Ab	4.5	0.228245	4.27
KSS Verkko Oy	3.76	0.267673	3.49
Kuopion Sähköverkko Oy	3.41	0.199878	3.21
Kuoreveden Sähkö Oy	3.9	0.297889	3.60
Kymenlaakson Sähköverkko Oy	2.41	0.26947	2.14
Lankosken Sähkö Oy	5.2	0.56624	4.63
Lappeenrannan Energiaverkot Oy	4.65	0.150181	4.50
Lehtimäen Sähkö Oy	4.5	0.544033	3.96
Leppäkosken Sähkö Oy	4.35	0.240003	4.11
LE-Sähköverkko Oy	3.47	0.196922	3.27
Kajave Oy	5.13	0.276956	4.85
Muonion Sähköosuuskunta	6.18	0.572035	5.61
Naantalin Energia Oy	4	0.222092	3.78
Nivos Energia Oy	4.08	0.157362	3.92
Nurmijärven Sähköverkko Oy	2.97	0.342026	2.63
Oulun Seudun Sähkö Verkkopalvelut Oy	2.48	0.221903	2.26
Paneliankosken Voima Oy	4.33	0.108	4.22
Parikkalan Valo Oy	3.4	0.230168	3.17
PKS Sähkösiirto Oy	4.7	1.813546	2.89
Pori Energia Sähköverkot Oy	3.43	0.214344	3.22
Porvoon Sähköverkko Oy	2.9	0.379861	2.52
Raahen Energia Oy	5.35	0.00141	5.35
Rantakairan Sähkö Oy	2.86	1.326399	1.53
Raseborgs Energi Ab - Raaseporin Energia Oy	3.94	0.318636	3.62
Rauman Energia Sähköverkko Oy	2.8	0.164244	2.64
Rovakaira Oy	1.96	0.332156	1.63
Rovaniemen Verkko Oy	2.25	0.222765	2.03
Sallila Sähkönsiirto Oy	4.3	0.233777	4.07
Savon Voima Verkko Oy	4.85	0.160282	4.69
Seiverkot Oy	3.21	0.166896	3.04
Sipoon Energia Oy	2.1	0.239787	1.86
Tampereen Sähköverkko Oy	3.1868	0.174783	3.01
Tenergia Oy	4.06	0.275587	3.78

Tornion Energia Oy	2.74	0.260881	2.48
TLS Verkko Oy	2.9	0.356273	2.54
Tunturiverkko Oy	2.88	0.552158	2.33
Turku Energia Sähköverkot Oy	1.75	0.185042	1.56
Vaasan Sähköverkko Oy	4.09	0.204592	3.89
Vakka-Suomen Voima Oy	4	0.199977	3.80
Valkeakosken Energia Oy	3.35	0.216316	3.13
Vantaan Energia Sähköverkot Oy	2.34	0.139891	2.20
Vatajankosken Sähköverkko Oy	4.44	0.305925	4.13
Verkko Korpela Oy	4	0.35437	3.65
Vetelin Energia Oy	4.29	0.151586	4.14
Vimpelin Voima Oy	4.02	0.273024	3.75