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Statistics Norway
Research Department

*Petter Vegard Hansen*

Documents

# Regional electricity spot price responses in Norway

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**Absctract:**
In this document we analyse the aggregate spotprice elasticities for 8 different regions in Norway. We estimate price elasticities for different weekdays and load periods. On the supply-side, we assume a horizontal supply-curve with stochastic shifts. This is reasonable in a hydropower system, and makes it possible to estimate the elasticities using OLS. The long run price elasticities for the regions are in the range from 0 to -0.12 in the winter season, and between 0.12 and -0.05 in the summer season.

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**Address:** Petter Vegard Hansen, Statistics Norway, Research Department P.O Box 8131 Dep., N-0033 Oslo, Norway. E-mail: petter.vegard.hansen@ssb.no

# 1 Introduction

An important element for energy studies is to analyse how consumers react to prices. These relationships are necessary in the modelling of the electricity market. Statistics Norway's model Normod-T is a model for the Nordic electricity market. The model has a detailed description of the supply side, which data include specific description of the power production system. The Norwegian demand is disaggregated into 8 regions, and each region is divided into different consumer groups. To improve the insight into consumer behaviour, we study the aggregate consumer demand response econometrically. We apply hourly data on aggregate demand and spot prices for the period January 2000 to December 2003. This period includes a high price period, which give us information on how the market reacts on extreme situations for different load periods and season.

There are very few studies estimating aggregate Norwegian spot price responses. Johnsen (2001) estimates the spot price elasticity in the Norway using weekly data. His estimated price elasticities are in the range -0.05 to -0.35. Peirson and Henley (1994) discuss the relationship between load and air temperature. They contribute with knowledge of the dynamics of electricity demand in econometric modelling. There are some studies using hourly data in forecasting of both price and demand. Knittel and Roberts (2001) do an empirical examination of the spot prices in the Californian market, and make clear some empirical properties with demand and prices in electricity markets. Prices move with demand, and move in cycles. However, the Norwegian market differs with respect to the great part of hydropower production, and is not necessary comparable.

The aim of this paper is to estimate price elasticitites for 8 Norwegian regions. We estimate the price elasticities for different days and load periods. The use of hourly data causes some methodical problems. Even if the data is hourly, very few customers are able to react on hourly basis. Every day and hour have some special properties, which we take into account by distinguishing between price responses at different time during a day, and in between different days.  This implies that the short run elasticities reflect weekly response, and the long run elasticities reflect the full effect of an increase in price carry out up 12 months.

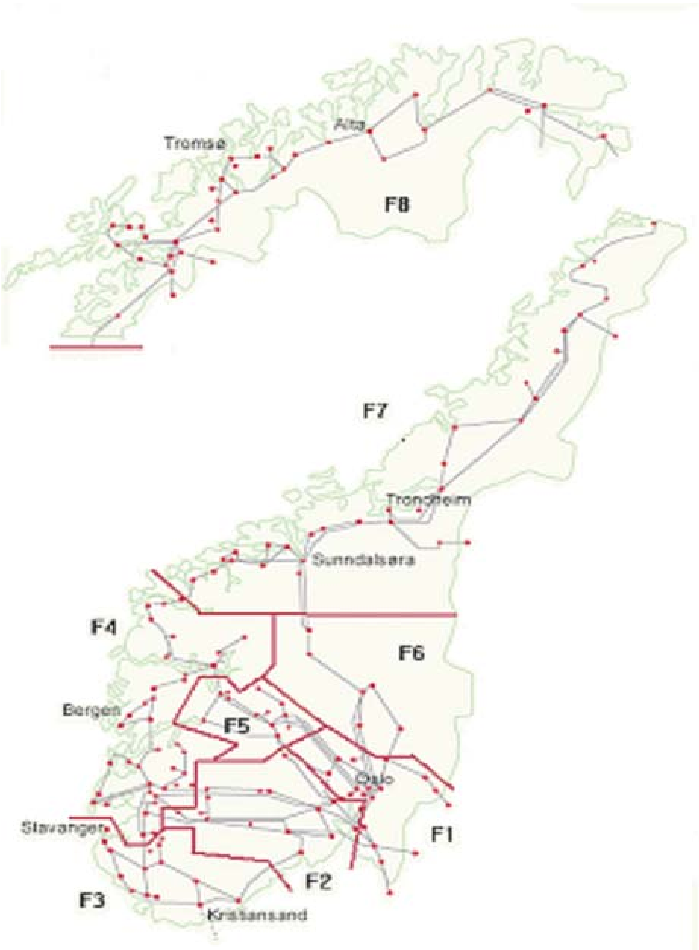
Since the power generation capacities limit is not met in the hydropower system, the price is determined by the inflow to the reservoir. This inflow, and hence the price, is stochastic. Since the supply function is horizontal in the short run with stochastic shifts, we use ordinary least square to estimate the price elasticities. In addition, this study identifies the characteristic of the data.

In the Section 2 we describe the properties of the data. In the Section 3 we discuss the econometric modelling. Further, in the Section 4 the estimation results are compared and discussed. Section 5 offers some concluding remarks.

# 2 Data

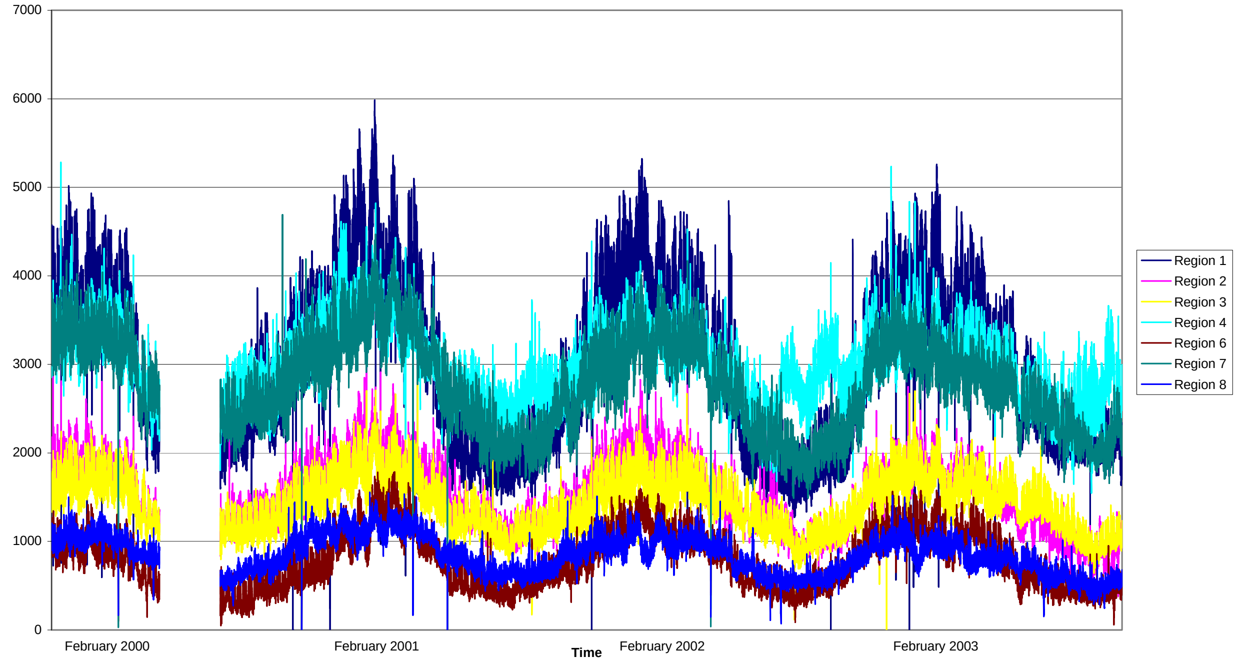
The Normod-T model divides Norway into 8 different regions, equal the regions used by the Norwegian transmission system operator (TSO), Statnett. The regions are divided such that the transmission system in the region does not have any transmission constraints, but there could possibly be transmission constraints between the regions. Figure 1 shows the regions, and includes the main grid.

**Figure 1. Statnetts 8 regions**



Statnett provides hourly data on demand for each region 1 to 8 in the period January 2000 to December 2003. There is a gap in the dataset from 17 may 2000 to 30 July 2000, which is left out from the estimation.

**Figure 2. Regional demand in MWh January 2000 to December 2003**




In figure 2 we have plotted the demand in each region. Region 5 is left out from the estimations because the consumption is very low, and the production relatively high. In some periods the loss in the grid in Region 5 is actually greater than consumption, hence it is not easy to measure the demand. We see that the demand is very cyclical, high demand in the winter season and low demand in the summer season. In addition there is a great variation around a trend. This is explained by the variation in temperature. Comparing the different regions, we see that the cycles are similar.

**Figure 3. Typical regional demand in MWh during a week**

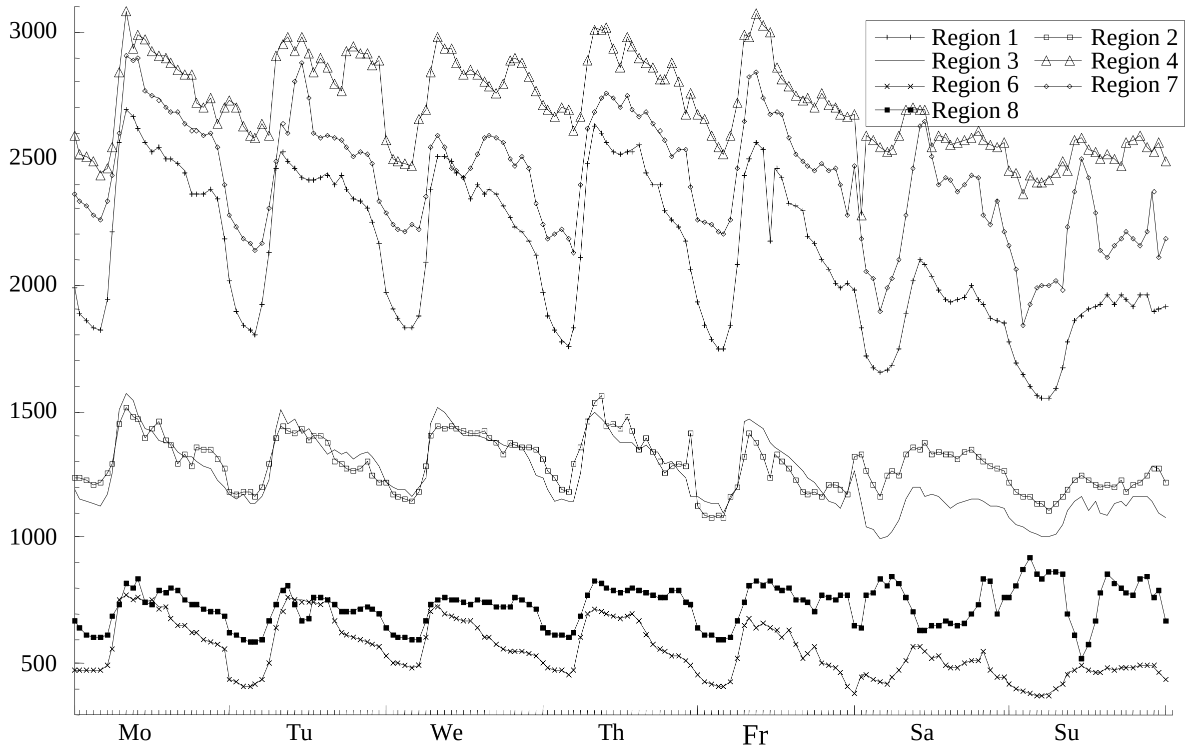
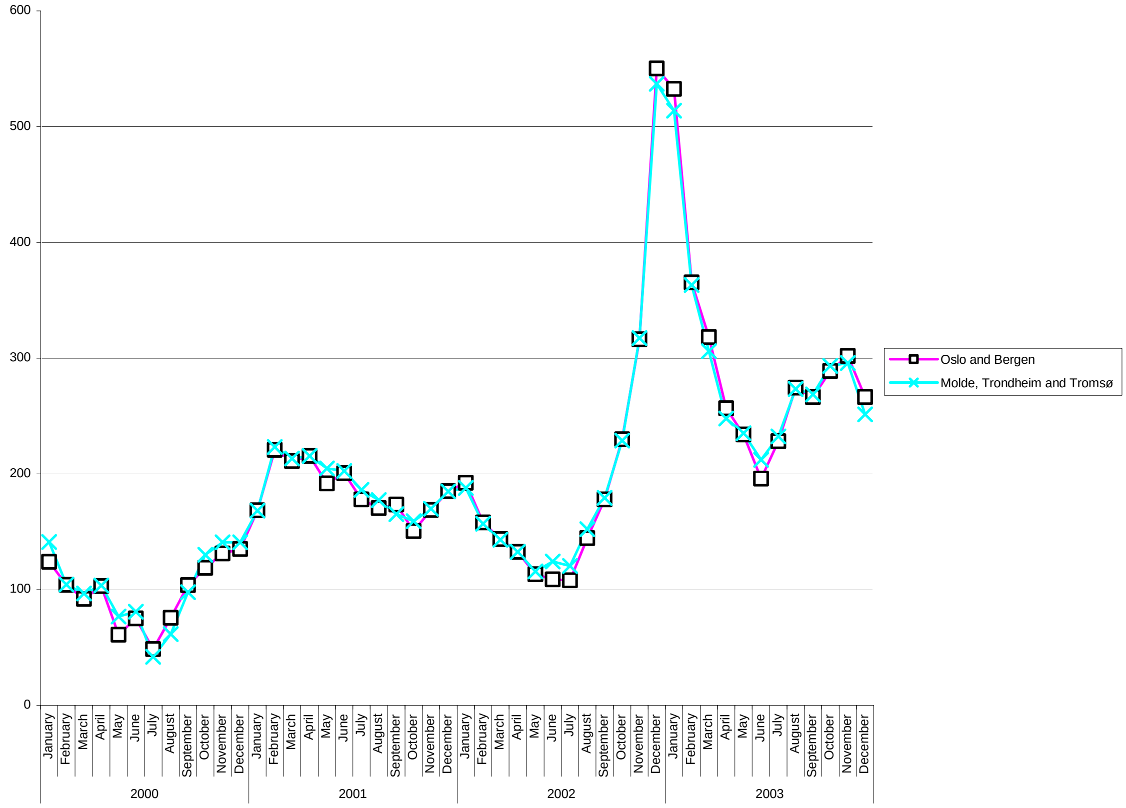


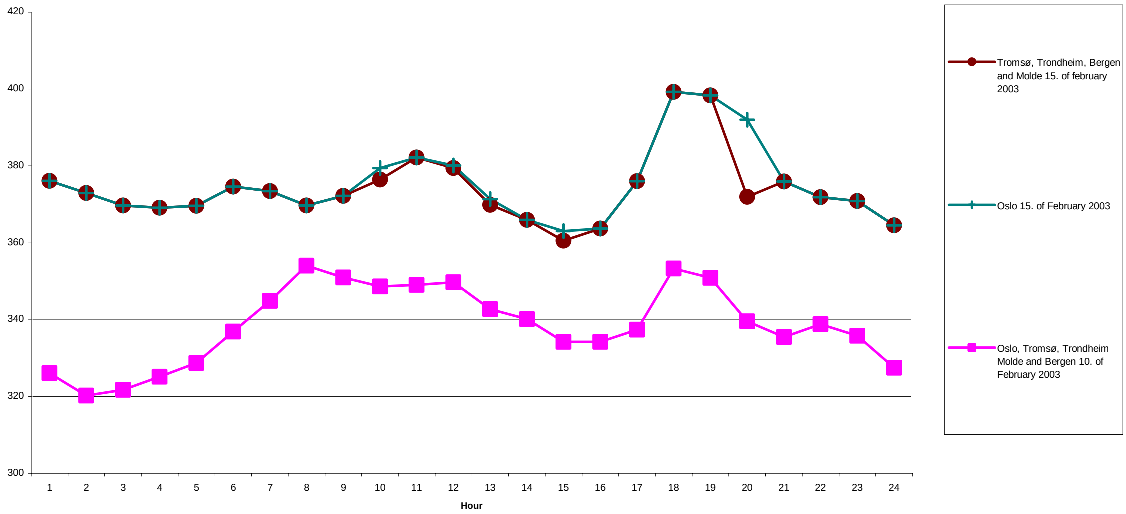

Figure 3 shows how the typical demand structure during a week for the regions. On the vertical axe, demand is measured in MWh for every hour through a week, Monday to Sunday. The demand is in general lower in the weekend than the rest of the week. The demand varies also during the week. We observe that the structure differs between regions.

The demand cycle influences the prices. Figure 4 shows that the prices are generally higher in the winter season than in the summer season, but we observe that the lowest price in 2003 is approximately the same as the highest price in 2001. This reflects that the stochastic part, inflow, is more important for the price variations than the difference between consumption in the different seasons and load periods. Further, in Figure 5 we have plotted two typical days to show price variation during the day. We see that the price does not vary as much as it does between seasons, but we observe some peak load pricing during the peak-hours 11-12 and 18-19. This has no implications for the estimations, since we do not estimate hourly demand response. Most of the time the price is the same in all regions. However, prices differ some hours due to the transmission constraints into the region. Then, the region needs a regional price to clear demand and supply. The spot prices are downloaded from Nordpool power exchange (www.Nordpool.no).

## Figure 4. Regional spot prices in NOK/MWh




## Figure 5. The spot price in NOK/MWh 10. and 15. of February 2003



Temperature is an important variable to explain how demand varies between seasons and from day to day. Norwegian Meteorological Institute provided us Temperature data. The data consist of daily observations for different metering stations in Norway, Oslo, Melsom, Stavanger, Kjevik, Bergen, Lillehammer (missing value is constructed from observations from Fagernes), Trondheim, Tromsø, and Bodø. The daily observations are interpolated to hourly frequency in order to be used together with the hourly data.

# 3 Econometric analyses

We derive the econometric specification from the general demand function. We assume a representative consumer that maximizes utility. The demand function is given by *D=f(P, T, S)*, the consumption of electricity depends of the price, *P*, temperature, *T*, and some seasonal and load specific variable *S*. From this general specification we have derive the econometric specification for demand in each region.

$$D^{r}_{ysdh} = \exp\left( \beta^{1r}_{ysdh} + \beta^{2r}_{ysdh} \ln P^{r}_{ysdh} + \beta^{3r}_{ysdh} T^{r}_{ysdh} + \beta^{4r}_{ysdh} \left( T^{r}_{ysdh} \right)^{2} + \beta^{5r}_{ysdh} \ln D^{r}_{ysdh-168} + \overline{\beta}^{6r}_{ysdh} \overline{S} \right) + \varepsilon_{ysdh}$$

We have the aggregate demand on the left-hand side. The time notation denotes *y* for year, *s* for week, *d* for day, *h* for hour and *r* for region. We assume constant elasticities with respect to price. $\beta^{2r}_{ysdh}$ is then the price elasticity for each region. The temperature, *T*, has both an exponential effect on demand, and an exponential effect on demand where the temperature is squared. This implies that we allow the demand to decrease when the temperature is under as certain level in the winter period. In the summer season the effect is opposite, when the temperature is over a certain level, the demand does not decrease more. Further, we include a 168 hour lag (one-week) in the demand function. $\overline{S}$ is a vector of dummies that take into account the cycles of the demand during seasons and hours. $\overline{\beta}^{6r}_{ysdh}$ is a vector of parameters belonging to the dummies and $\varepsilon_{ysdh}$ are the residuals.

In order to identify the price-elasticity during a 24-hour period, we started out estimating weekly short run elasticities hour for hour, and day by day on aggregated demand. It is likely that different weekdays have different properties, and that the price-response varies from hour to hour. An other reason for choosing weekly price-response is the possibility for extending the model to a simultaneous model. On the supply-side we only have weekly observation on the shift-variables.

We have distinguished between summer and winter seasons. The summer season is from May 1st to October 1st, and the winter season from October 1st to May 1st . We assume that the price elasticity is the same for some hours, and the interval is reported in the figures and tables below.

# 4 Results

## 4.1 Overview

The estimations are done in SAS, using the procmod function. To get an overview of the estimations, we report the average short run and long run elasticities for the summer and winter season in the different regions. In general, the price response is greater in the winter season than in the summer season, except for Region 2, where the summer elasticity is very high. We see that for most of the regions, the summer elasticities are positive. This indicates that our assumption of horizontal supply-curve does not hold. The simultaneity bias should be the same for all regions, and we can still compare the response between regions. However, the results indicate small or no price response in the summer seasons for four of the regions. In the winter season, we observe price elasticities from about -0.01 to -0.06 in the short run, and -0.01 to -0.12 in the long run. Table 1 gives an overview of the distribution of power consumption for each region. This overview is not accurate, since we use consumption for each county in Norway to calculate the distribution in the regions set up by Statnett. These counties are not exactly transferable to the regions set up by Statnett. However, they give a good overview on the distribution of consumption in each region.

**Table 1. Distribution of power consumption in each region in percent**

| | Wood processing industry | Power intensive industries | Mining and other industry | Transport and communication | Business sector | Households and agriculture |
|---|---|---|---|---|---|---|
| Region 1 | 11 | 2 | 7 | 4 | 34 | 41 |
| Region 2 | 16 | 15 | 11 | 1 | 20 | 37 |
| Region 3 | 2 | 47 | 7 | 1 | 16 | 27 |
| Region 4 | 0 | 49 | 4 | 1 | 22 | 24 |
| Region 6 | 0 | 0 | 15 | 3 | 29 | 53 |
| Region 7 | 10 | 31 | 7 | 1 | 20 | 31 |
| Region 8 | 0 | 40 | 7 | 1 | 20 | 32 |

Source: Statistics Norway

Table 2. Average price elasticities for each region

| | Summer | | Winter | |
|---|---|---|---|---|
| | Short run | Long run | Short run | Long run |
| Region 1 | 0.011 | 0.018 | -0.053 | -0.066 |
| Region 2 | -0.080 | -0.127 | -0.056 | -0.095 |
| Region 3 | 0.007 | 0.009 | -0.025 | -0.033 |
| Region 4 | 0.007 | 0.008 | -0.034 | -0.043 |
| Region 6 | 0.045 | 0.077 | -0.006 | -0.013 |
| Region 7 | -0.002 | -0.002 | -0.037 | -0.066 |
| Region 8 | -0.011 | -0.017 | -0.063 | -0.116 |

**Figure 6. Short run price elasticities summer season over weekdays and hours**

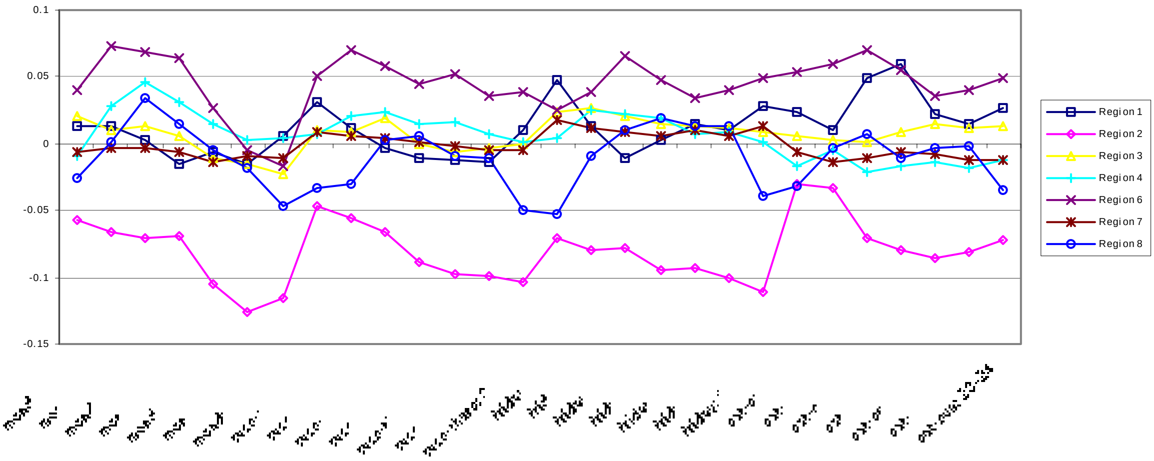



**Figure 7. Short run price elasticities winter season over weekdays and hours**

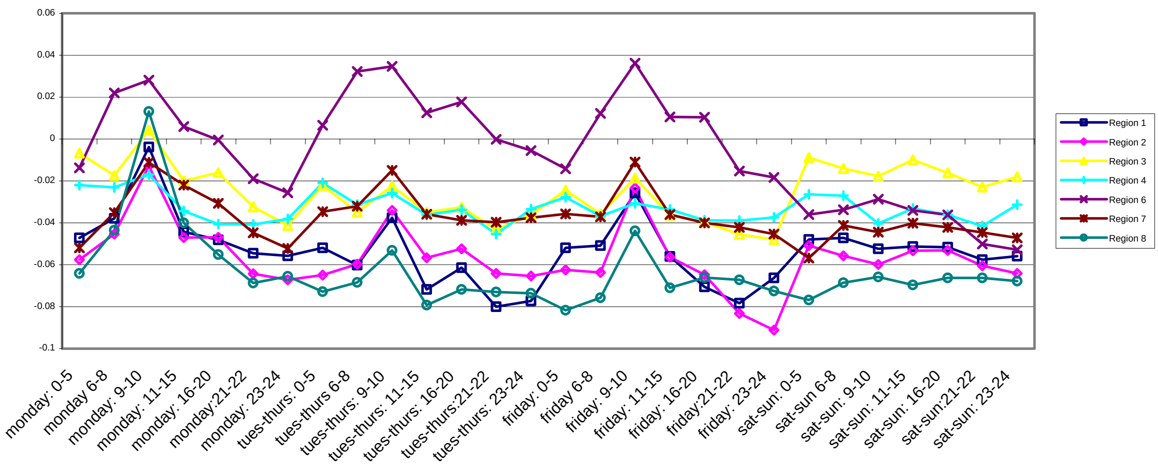


Figure 6 and 7 plot the short run price elasticities for each load period on the horizontal axe for each region in the summer and the winter season. In the summer season, there is some correlation between the price elasticities. However, in the winter season this, correlation is much higher. This indicates that the price elasticity in the summer is very low, and that the demand for electricity is determined by other variables. In the winter period, all the average price elasticities for the regions are negative. The elasticities in the hours 9-10 is in general low on weekdays, especially Mondays 9-10.

## 4.2 Region 1

The price elasticity in the summer varies around zero, on average 0.01, and positive for Region 1. This is not as expected, since rational consumers do not increase consumption when the price increase. The reason can be that the price variation during the summer period has not been high enough for the consumers to react. The possibilities to substitute electricity are also smaller than during the winter period.

**Table 3. Short run and long run price elasticities for Region 1**

| | Summer | | Winter | |
|---|---|---|---|---|
| Interval | Short run | Long run | Short run | Long run |
| Monday: 0-5 | 0.013 | 0.021 | -0.047 | -0.066 |
| Monday: 6-8 | 0.012 | 0.015 | -0.038 | -0.048 |
| Monday: 9-10 | 0.002 | 0.002 | -0.004 | -0.005 |
| Monday: 11-15 | -0.015 | -0.019 | -0.044 | -0.057 |
| Monday: 16-20 | -0.006 | -0.008 | -0.048 | -0.057 |
| Monday: 21-22 | -0.016 | -0.018 | -0.054 | -0.073 |
| Monday: 23-24 | 0.005 | 0.006 | -0.056 | -0.077 |
| Tues-Thurs: 0-5 | 0.031 | 0.052 | -0.052 | -0.072 |
| Tues-Thurs 6-8 | 0.012 | 0.018 | -0.060 | -0.076 |
| Tues-Thurs: 9-10 | -0.004 | -0.005 | -0.038 | -0.048 |
| Tues-Thurs: 11-15 | -0.010 | -0.015 | -0.072 | -0.086 |
| Tues-Thurs: 16-20 | -0.013 | -0.018 | -0.061 | -0.065 |
| Tues-Thurs: 21-22 | -0.013 | -0.018 | -0.080 | -0.084 |
| Tues-Thurs: 23-24 | 0.010 | 0.014 | -0.077 | -0.089 |
| Friday: 0-5 | 0.047 | 0.078 | -0.052 | -0.070 |
| Friday: 6-8 | 0.014 | 0.020 | -0.051 | -0.061 |
| Friday: 9-10 | -0.011 | -0.018 | -0.026 | -0.029 |
| Friday: 11-15 | 0.002 | 0.004 | -0.056 | -0.073 |
| Friday: 16-20 | 0.014 | 0.022 | -0.071 | -0.087 |
| Friday: 21-22 | 0.011 | 0.015 | -0.078 | -0.088 |
| Friday: 23-24 | 0.027 | 0.040 | -0.066 | -0.078 |
| Sat-Sun: 0-5 | 0.023 | 0.043 | -0.048 | -0.053 |
| Sat-Sun: 6-8 | 0.010 | 0.017 | -0.047 | -0.068 |
| Sat-Sun: 9-10 | 0.049 | 0.073 | -0.052 | -0.072 |
| Sat-Sun: 11-15 | 0.059 | 0.089 | -0.051 | -0.064 |
| Sat-Sun: 16-20 | 0.022 | 0.033 | -0.052 | -0.063 |
| Sat-Sun: 21-22 | 0.015 | 0.022 | -0.058 | -0.074 |
| Sat-Sun: 23-24 | 0.027 | 0.041 | -0.056 | -0.070 |

Looking at the price response during the winter season, we see that it varies between -0.03 and -0.07 in the short run, and is up to -0.09 in the long run. Most of the price response is completed after a few weeks. 75 percent of the demand comes from the service and residential sector, which can explain that we do not have any price response in the summer season. The possibilities to save energy are lower in the summer. However, the response in the winter is quite high if we compare with Region 6, which also have a great part of non-industrial customers.

## 4.3 Region 2

Region 2 differs from Region 1. The price-response is high in the summer season in Region 2. Power intensive industry and other industries constitute about 42 percent of the total demand. The relatively low price elasticity in Region 1 with a great service and residential sector indicates that the reduction in consumption comes from the industrial sector that has opportunity to reduce demand in the summer season.

**Table 4. Short run and long run price elasticities for Region 2**

| | Summer | | Winter | |
|---|---|---|---|---|
| Interval | Short run | Long run | Short run | Long run |
| Monday: 0-5 | -0.057 | -0.088 | -0.058 | -0.087 |
| Monday: 6-8 | -0.067 | -0.103 | -0.045 | -0.069 |
| Monday: 9-10 | -0.070 | -0.115 | -0.013 | -0.021 |
| Monday: 11-15 | -0.070 | -0.114 | -0.047 | -0.079 |
| Monday: 16-20 | -0.105 | -0.163 | -0.047 | -0.083 |
| Monday: 21-22 | -0.127 | -0.169 | -0.064 | -0.104 |
| Monday: 23-24 | -0.116 | -0.190 | -0.067 | -0.108 |
| Tues-Thurs: 0-5 | -0.046 | -0.083 | -0.065 | -0.114 |
| Tues-Thurs: 6-8 | -0.056 | -0.088 | -0.060 | -0.098 |
| Tues-Thurs: 9-10 | -0.066 | -0.098 | -0.034 | -0.055 |
| Tues-Thurs: 11-15 | -0.088 | -0.125 | -0.057 | -0.095 |
| Tues-Thurs: 16-20 | -0.097 | -0.147 | -0.052 | -0.089 |
| Tues-Thurs: 21-22 | -0.099 | -0.154 | -0.064 | -0.115 |
| Tues-Thurs: 23-24 | -0.104 | -0.157 | -0.065 | -0.114 |
| Friday: 0-5 | -0.071 | -0.120 | -0.062 | -0.128 |
| Friday: 6-8 | -0.080 | -0.114 | -0.064 | -0.112 |
| Friday: 9-10 | -0.079 | -0.128 | -0.023 | -0.045 |
| Friday: 11-15 | -0.095 | -0.148 | -0.056 | -0.104 |
| Friday: 16-20 | -0.094 | -0.150 | -0.065 | -0.116 |
| Friday: 21-22 | -0.101 | -0.146 | -0.083 | -0.139 |
| Friday: 23-24 | -0.111 | -0.162 | -0.091 | -0.128 |
| Sat-Sun: 0-5 | -0.031 | -0.058 | -0.051 | -0.081 |
| Sat-Sun: 6-8 | -0.033 | -0.063 | -0.056 | -0.092 |
| Sat-Sun: 9-10 | -0.071 | -0.137 | -0.060 | -0.100 |
| Sat-Sun: 11-15 | -0.079 | -0.147 | -0.053 | -0.084 |
| Sat-Sun: 16-20 | -0.085 | -0.138 | -0.053 | -0.085 |
| Sat-Sun: 21-22 | -0.081 | -0.134 | -0.061 | -0.104 |
| Sat-Sun: 23-24 | -0.072 | -0.126 | -0.064 | -0.105 |

## 4.4 Region 3

Region 3 is a region with general low price responses both in the summer and the winter season. In the summer season, the elasticities are positive during most of the week. In the periods with negative elasticities, the number is very low. For the winter season, the response is negative in all load periods. The effect is from -0.01 to -0.06 in the long run, and since the difference between the short run and long run elasticities is small, the price response is completed during a few weeks. Region 3 is the region where only 43 percent of the demand comes from the service sector and households. In general a great part of power intensive industry has usually a high price response.

**Table 5. Short run and long run price elasticities for Region 3**

| | Summer | | Winter | |
|---|---|---|---|---|
| Interval | Short run | Long run | Short run | Long run |
| Monday: 0-5 | 0.021 | 0.032 | -0.007 | -0.008 |
| Monday: 6-8 | 0.010 | 0.013 | -0.017 | -0.020 |
| Monday: 9-10 | 0.013 | 0.014 | 0.004 | 0.005 |
| Monday: 11-15 | 0.006 | 0.009 | -0.020 | -0.026 |
| Monday: 16-20 | -0.011 | -0.017 | -0.016 | -0.021 |
| Monday: 21-22 | -0.016 | -0.024 | -0.032 | -0.039 |
| Monday: 23-24 | -0.023 | -0.032 | -0.041 | -0.049 |
| Tues-Thurs: 0-5 | 0.011 | 0.015 | -0.022 | -0.031 |
| Tues-Thurs 6-8 | 0.009 | 0.013 | -0.035 | -0.046 |
| Tues-Thurs: 9-10 | 0.019 | 0.025 | -0.023 | -0.029 |
| Tues-Thurs: 11-15 | 0.000 | 0.000 | -0.035 | -0.047 |
| Tues-Thurs: 16-20 | -0.006 | -0.008 | -0.033 | -0.044 |
| Tues-Thurs: 21-22 | -0.004 | -0.005 | -0.043 | -0.058 |
| Tues-Thurs: 23-24 | 0.000 | 0.000 | -0.036 | -0.048 |
| Friday: 0-5 | 0.023 | 0.033 | -0.024 | -0.033 |
| Friday: 6-8 | 0.026 | 0.029 | -0.036 | -0.048 |
| Friday: 9-10 | 0.021 | 0.025 | -0.019 | -0.023 |
| Friday: 11-15 | 0.014 | 0.018 | -0.036 | -0.049 |
| Friday: 16-20 | 0.013 | 0.021 | -0.040 | -0.052 |
| Friday: 21-22 | 0.012 | 0.016 | -0.045 | -0.061 |
| Friday: 23-24 | 0.009 | 0.010 | -0.048 | -0.060 |
| Sat-Sun: 0-5 | 0.006 | 0.007 | -0.009 | -0.011 |
| Sat-Sun: 6-8 | 0.003 | 0.003 | -0.014 | -0.019 |
| Sat-Sun: 9-10 | 0.002 | 0.002 | -0.018 | -0.023 |
| Sat-Sun: 11-15 | 0.009 | 0.013 | -0.010 | -0.013 |
| Sat-Sun: 16-20 | 0.015 | 0.021 | -0.016 | -0.022 |
| Sat-Sun: 21-22 | 0.012 | 0.016 | -0.023 | -0.029 |
| Sat-Sun: 23-24 | 0.012 | 0.015 | -0.018 | -0.021 |

However, special price contracts, and the introduction of new industry can explain the relatively low price elasticity compared with other regions where power intensive industries also constitute a great part.

## 4.5 Region 4

In Region 4 the price effect in the summer is actually greater in the weekend than in the rest of the week, where the estimated elasticities are positive. In the winter, the response is -0.03 to -0.06 in the long- run with the lowest values during the hours 0 to 5, and highest response in the peak load hours. In this region, 46 percent of the demand comes from the services sector and households. The great share of power intensive industry does not seem to affect the price elasticity. This indicates relatively low price responses from the power intensive industry in this region.

**Table 6. Short run and long run price elasticities for Region 4**

| | Summer | | Winter | |
|---|---|---|---|---|
| Interval | Short run | Long run | Short run | Long run |
| Monday: 0-5 | -0.009 | -0.012 | -0.022 | -0.030 |
| Monday: 6-8 | 0.029 | 0.034 | -0.023 | -0.027 |
| Monday: 9-10 | 0.046 | 0.050 | -0.017 | -0.018 |
| Monday: 11-15 | 0.031 | 0.040 | -0.034 | -0.044 |
| Monday: 16-20 | 0.015 | 0.019 | -0.041 | -0.052 |
| Monday: 21-22 | 0.003 | 0.004 | -0.041 | -0.047 |
| Monday: 23-24 | 0.005 | 0.006 | -0.038 | -0.046 |
| Tues-Thurs: 0-5 | 0.007 | 0.011 | -0.021 | -0.030 |
| Tues-Thurs 6-8 | 0.021 | 0.030 | -0.031 | -0.041 |
| Tues-Thurs: 9-10 | 0.023 | 0.030 | -0.026 | -0.032 |
| Tues-Thurs: 11-15 | 0.014 | 0.019 | -0.036 | -0.046 |
| Tues-Thurs: 16-20 | 0.016 | 0.023 | -0.034 | -0.045 |
| Tues-Thurs: 21-22 | 0.007 | 0.009 | -0.045 | -0.057 |
| Tues-Thurs: 23-24 | 0.001 | 0.001 | -0.033 | -0.043 |
| Friday: 0-5 | 0.004 | 0.006 | -0.028 | -0.040 |
| Friday: 6-8 | 0.025 | 0.032 | -0.037 | -0.047 |
| Friday: 9-10 | 0.022 | 0.029 | -0.031 | -0.040 |
| Friday: 11-15 | 0.019 | 0.025 | -0.034 | -0.050 |
| Friday: 16-20 | 0.007 | 0.010 | -0.039 | -0.052 |
| Friday: 21-22 | 0.008 | 0.011 | -0.039 | -0.052 |
| Friday: 23-24 | 0.001 | 0.001 | -0.037 | -0.048 |
| Sat-Sun: 0-5 | -0.017 | -0.023 | -0.026 | -0.031 |
| Sat-Sun: 6-8 | -0.005 | -0.006 | -0.027 | -0.041 |
| Sat-Sun: 9-10 | -0.021 | -0.028 | -0.040 | -0.055 |
| Sat-Sun: 11-15 | -0.017 | -0.023 | -0.033 | -0.047 |
| Sat-Sun: 16-20 | -0.014 | -0.019 | -0.036 | -0.046 |
| Sat-Sun: 21-22 | -0.019 | -0.026 | -0.042 | -0.051 |
| Sat-Sun: 23-24 | -0.012 | -0.017 | -0.031 | -0.040 |

## 4.6 Region 6

The price response in Region 6 is in general low. It is a small region with no power intensive industry. 82 percent of the consumption comes from the service sector and households. The price elasticity is the lowest in average for all regions, which indicates that households have small possibilities to decrease their demand in the summer season. In the winter, the price elasticity is negative and low, but not as low as in Region 1, that also has a small share of industry. The elasticities are positive in some load periods, and with very high response in other periods, up to -0.10 in the long run in the weekend. In the summer season, the estimated results are positive for all load periods.

**Table 7. Short run and long run price elasticities for Region 6**

| | Summer | | Winter | |
|---|---|---|---|---|
| Interval | Short run | Long run | Short run | Long run |
| Monday: 0-5 | 0.039 | 0.072 | -0.014 | -0.025 |
| Monday: 6-8 | 0.073 | 0.119 | 0.022 | 0.033 |
| Monday: 9-10 | 0.068 | 0.096 | 0.028 | 0.042 |
| Monday: 11-15 | 0.063 | 0.096 | 0.006 | 0.009 |
| Monday: 16-20 | 0.027 | 0.047 | 0.000 | -0.001 |
| Monday: 21-22 | -0.005 | -0.009 | -0.019 | -0.034 |
| Monday: 23-24 | -0.016 | -0.035 | -0.026 | -0.049 |
| Tues-Thurs: 0-5 | 0.051 | 0.101 | 0.007 | 0.013 |
| Tues-Thurs 6-8 | 0.069 | 0.117 | 0.032 | 0.051 |
| Tues-Thurs: 9-10 | 0.059 | 0.089 | 0.035 | 0.053 |
| Tues-Thurs: 11-15 | 0.045 | 0.070 | 0.012 | 0.021 |
| Tues-Thurs: 16-20 | 0.052 | 0.081 | 0.018 | 0.029 |
| Tues-Thurs: 21-22 | 0.035 | 0.056 | 0.000 | 0.000 |
| Tues-Thurs: 23-24 | 0.038 | 0.062 | -0.006 | -0.011 |
| Friday: 0-5 | 0.025 | 0.055 | -0.014 | -0.030 |
| Friday: 6-8 | 0.038 | 0.075 | 0.012 | 0.020 |
| Friday: 9-10 | 0.065 | 0.102 | 0.036 | 0.052 |
| Friday: 11-15 | 0.048 | 0.081 | 0.011 | 0.017 |
| Friday: 16-20 | 0.034 | 0.067 | 0.010 | 0.017 |
| Friday: 21-22 | 0.040 | 0.066 | -0.015 | -0.026 |
| Friday: 23-24 | 0.048 | 0.080 | -0.018 | -0.034 |
| Sat-Sun: 0-5 | 0.053 | 0.110 | -0.036 | -0.065 |
| Sat-Sun: 6-8 | 0.059 | 0.109 | -0.034 | -0.063 |
| Sat-Sun: 9-10 | 0.070 | 0.125 | -0.029 | -0.052 |
| Sat-Sun: 11-15 | 0.056 | 0.098 | -0.034 | -0.064 |
| Sat-Sun: 16-20 | 0.035 | 0.065 | -0.036 | -0.072 |
| Sat-Sun: 21-22 | 0.040 | 0.075 | -0.050 | -0.097 |
| Sat-Sun: 23-24 | 0.049 | 0.090 | -0.053 | -0.101 |

## 4.7 Region 7

In this region, the price response is negative in almost all load periods and seasons. The industrial demand share is 48 percent. The negative price elasticity in the summer indicates that the industry has reduced the consumption during high prices. In the winter season, we see that the average price elasticity is the same as in the long run as for Region 1. However, the response is much slower in this region, since the difference between the long- and short run results are greater here.

**Table 9. Short run and long run price elasticities for Region 7**

| | Summer | | Winter | |
|---|---|---|---|---|
| Interval | Short run | Long run | Short run | Long run |
| Monday: 0-5 | -0.007 | -0.012 | -0.052 | -0.083 |
| Monday: 6-8 | -0.004 | -0.006 | -0.035 | -0.060 |
| Monday: 9-10 | -0.004 | -0.005 | -0.011 | -0.020 |
| Monday: 11-15 | -0.007 | -0.011 | -0.022 | -0.037 |
| Monday: 16-20 | -0.013 | -0.019 | -0.031 | -0.054 |
| Monday: 21-22 | -0.009 | -0.016 | -0.045 | -0.084 |
| Monday: 23-24 | -0.011 | -0.020 | -0.052 | -0.097 |
| Tues-Thurs: 0-5 | 0.009 | 0.014 | -0.035 | -0.065 |
| Tues-Thurs 6-8 | 0.005 | 0.009 | -0.032 | -0.055 |
| Tues-Thurs: 9-10 | 0.004 | 0.007 | -0.015 | -0.025 |
| Tues-Thurs: 11-15 | 0.001 | 0.002 | -0.036 | -0.061 |
| Tues-Thurs: 16-20 | -0.002 | -0.003 | -0.039 | -0.064 |
| Tues-Thurs: 21-22 | -0.005 | -0.009 | -0.040 | -0.070 |
| Tues-Thurs: 23-24 | -0.005 | -0.008 | -0.038 | -0.069 |
| Friday: 0-5 | 0.017 | 0.035 | -0.036 | -0.064 |
| Friday: 6-8 | 0.012 | 0.024 | -0.037 | -0.067 |
| Friday: 9-10 | 0.009 | 0.018 | -0.011 | -0.018 |
| Friday: 11-15 | 0.005 | 0.011 | -0.036 | -0.066 |
| Friday: 16-20 | 0.009 | 0.016 | -0.040 | -0.072 |
| Friday: 21-22 | 0.005 | 0.009 | -0.042 | -0.075 |
| Friday: 23-24 | 0.013 | 0.021 | -0.045 | -0.080 |
| Sat-Sun: 0-5 | -0.007 | -0.012 | -0.057 | -0.064 |
| Sat-Sun: 6-8 | -0.013 | -0.021 | -0.041 | -0.078 |
| Sat-Sun: 9-10 | -0.011 | -0.017 | -0.044 | -0.078 |
| Sat-Sun: 11-15 | -0.006 | -0.010 | -0.040 | -0.078 |
| Sat-Sun: 16-20 | -0.008 | -0.013 | -0.042 | -0.082 |
| Sat-Sun: 21-22 | -0.013 | -0.020 | -0.045 | -0.083 |
| Sat-Sun: 23-24 | -0.012 | -0.020 | -0.047 | -0.086 |

## 4.8 Region 8

Region 8 is the region with the greatest winter response. The response is between -0.08 and -0.16. In the summer season, there is a significantly negative price response, the highest of all regions. The distribution of demand is quite similar to Region 7, and total demand is approximately the same. We observe some of the same elements in the price elasticity structure, however, the response is much higher in this region. Since the region is small, the response from one industrial customer will have a great effect on the aggregate price elasticity.

**Table 10. Short run and long run price elasticities for Region 8**

| | Summer | | Winter | |
|---|---|---|---|---|
| Interval | Short run | Long run | Short run | Long run |
| Monday: 0-5 | -0.026 | -0.035 | -0.064 | -0.131 |
| Monday: 6-8 | 0.002 | 0.002 | -0.044 | -0.077 |
| Monday: 9-10 | 0.034 | 0.042 | 0.013 | 0.024 |
| Monday: 11-15 | 0.014 | 0.017 | -0.040 | -0.076 |
| Monday: 16-20 | -0.005 | -0.006 | -0.055 | -0.108 |
| Monday: 21-22 | -0.018 | -0.022 | -0.069 | -0.130 |
| Monday: 23-24 | -0.046 | -0.070 | -0.066 | -0.124 |
| Tues-Thurs: 0-5 | -0.033 | -0.043 | -0.073 | -0.140 |
| Tues-Thurs 6-8 | -0.030 | -0.042 | -0.068 | -0.120 |
| Tues-Thurs: 9-10 | 0.003 | 0.004 | -0.053 | -0.090 |
| Tues-Thurs: 11-15 | 0.006 | 0.008 | -0.079 | -0.126 |
| Tues-Thurs: 16-20 | -0.010 | -0.014 | -0.072 | -0.117 |
| Tues-Thurs: 21-22 | -0.011 | -0.015 | -0.073 | -0.122 |
| Tues-Thurs: 23-24 | -0.050 | -0.080 | -0.074 | -0.125 |
| Friday: 0-5 | -0.052 | -0.069 | -0.082 | -0.132 |
| Friday: 6-8 | -0.010 | -0.013 | -0.076 | -0.128 |
| Friday: 9-10 | 0.010 | 0.015 | -0.044 | -0.075 |
| Friday: 11-15 | 0.019 | 0.025 | -0.071 | -0.116 |
| Friday: 16-20 | 0.014 | 0.018 | -0.066 | -0.119 |
| Friday: 21-22 | 0.013 | 0.019 | -0.067 | -0.139 |
| Friday: 23-24 | -0.039 | -0.064 | -0.073 | -0.161 |
| Sat-Sun: 0-5 | -0.032 | -0.049 | -0.077 | -0.131 |
| Sat-Sun 6-8 | -0.003 | -0.005 | -0.069 | -0.136 |
| Sat-Sun: 9-10 | 0.006 | 0.009 | -0.066 | -0.129 |
| Sat-Sun: 11-15 | -0.010 | -0.016 | -0.070 | -0.136 |
| Sat-Sun: 16-20 | -0.003 | -0.005 | -0.066 | -0.120 |
| Sat-Sun: 21-22 | -0.002 | -0.004 | -0.066 | -0.122 |
| Sat-Sun: 23-24 | -0.035 | -0.068 | -0.068 | -0.130 |

## 4.9 Temperature effects

The temperature has an important effect on the demand, and this effect is significant in our model. In the winter season, we allow the demand to decrease from a maximum demand when the temperature decreases further. In the summer we have the opposite effect.  Between the hours 16-20 Tuesday through Thursday, this effect is significant for all regions except Region 4 and Region 8. Table 11 shows at which the temperature the maximum load is expected in the winter, and minimum load in the summer seasons.

**Table 11. Temperature that gives the maximum and minimum demand**

| | Temperature that gives maximum demand in the winter season | Temperature that gives minimum load in the summer season. |
|---|---|---|
| Region 1 | -23.52* | 32.19* |
| Region 2 | -18.29* | 167.99 |
| Region 3 | -25* | 23.14* |
| Region 4 | No maximum | 16.04* |
| Region 6 | -20.52383* | 17.55* |
| Region 7 | -16.214546* | 36.46* |
| Region 8 | -170.73 | 123.69 |

* Both the linear and quadratic elements are significant on a 5 percent level

# 5 Concluding remarks

The aim of this study was to estimate the price elasticities in different regions of Norway.
In the summer season, the results indicate no or very small price responses for all regions expect for Region 2. In the winter season, the negative price responses are significant for all regions. There is a correlation between the price responses, especially in the winter season, between all regions. The differences can be explained by the demand structure. The share of industrial and non-industrial customers varies much between regions.

The study indicates that the demand-response is higher during the winter than the summer. In regions with higher share of industry, there is a greater potential for reduction of consumption during high price periods. This is especially relevant in the summer, when the potential reduction in consumption is small for the service sector and residential customers. We cannot conclude that a greater share of industrial demand implies high price response, but we observe that in regions with a great share of industrial demand, the price response is higher.

Ordinary least square identifies some important elements of the demand structure for the different regions. However, this implies some strong assumptions about the supply side. The next step is to model the supply side, and to use some shift variables, which can explain the changes in price. Since the bias is the same for all the regions, this study gives knowledge about the variation in price elasticities between regions. This analyse on hourly data gives us important knowledge for estimations within a simultaneously model.

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