Informationsklass
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Report on Reduction of gross electricity consumption during peak hours in Sweden for March 2023

According to article 4(2) in Council Regulation 2022/1854, each Member State shall reduce its gross electricity consumption during the identified peak hours. The reduction achieved over the identified peak hours shall reach at least 5% on average per hour.

The reduction is calculated from the difference between the actual gross electricity consumption for the identified peak hours and the gross electricity consumption forecasted by the transmission system operators. Svenska kraftnät´s forecast for February 2023 is based on historical data of the reference period specified in Article 2.3 of Regulation 2022/1854 and adjusted due to temperature differences.

The temperatures in March 2023 were 0-3 °C colder than during the reference period which led to quite large positive adjustments of the forecast. No adjustments were made due to electrification (new large industries etc.).

The consumption during peak hours in March 2023 was reduced with 9.0% as compared to the forecast, see Table 1.

Definitions and the method for estimating reduction during peak hours in Sweden are described in Appendix 1.

Table 1. Results for peak hours in February 2023. All numbers are given in MW.

	Average consumption last five years	Temperature adjustments	Electrification adjustments	Consumption forecast	Observed consumption	Consumption change
SE1	1375	59	0	1434	1448	14 (1.0%)
SE2	2223	102	0	2325	2111	-214 (-9.2%)
SE3	12115	439	0	12554	11442	-1112 (-8.9%)
SE4	3505	30	0	3536	3064	-472 (-13.3%)
Sweden	19218	630	0	19848	18065	-1783 **(-9.0%**)

Appendix 1. Method for estimating reduction of gross electricity consumption during peak hours in Sweden

According to article 4(2) in Council Regulation 2022/1854, each Member State shall reduce its gross electricity consumption during the identified peak hours. The reduction achieved over the identified peak hours shall reach at least 5 % on average per hour compared to a forecast based on a baseline period consisting of the last five years. The peak hours for Sweden are defined as hours 8, 9, 10, 16, 17 and 18 UTC+1 during non-holiday weekdays in December to March. The change for a particular period (e.g., one month) is defined as:

Change = observed consumption – consumption forecast

= observed consumption – (baseline forecast + adjustments)

The “baseline forecast” is the average consumption for the same period during the previous five years. “Adjustments” are based on temperature differences and potentially significant and known changes in industrial loads.

The remainder of this document is structured as follows. First, input data is described and peak hours are defined. After that, an overview of the method is given. The document concludes with Sections 4-6 detailing the computation of adjustment terms.

1. Input data

The consumption is official “settlement” data, originally from the eSett system[1]. Settlement data is based on the economical transfer system and has high quality. Changes to eSett metered/settlement data are allowed up to 14 days after the day in question, which means that e.g. data for the entire period of December 2022 is firmly available the 14th of January 2023. Note that for consumers with both production and consumption, only the net consumption is considered. This applies for e.g. households with PV systems and industries with internal generation of electricity.

For temperature adjustments, data from the meteorological model ERA5 from the European weather center (ECMWF) is used[2]. Modelled temperature 2m above ground is retrieved with a resolution of 0.5 degrees in latitude and longitude which implies around 400 grid points over Sweden.

[1] https://www.esett.com/
[2] https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/qj.3803

All data has an hourly resolution and represent hourly means, e.g. hour 8 refers to the average load during the period 08:00 – 09:00. Timestamps are in local Swedish time (UTC+1 during the winter period).

2. Definition of peak hours

The peak hours are defined as hours 8, 9, 10, 16, 17 and 18 during weekdays (Monday – Friday) in December to March. Holidays and bridge days are excluded. This definition of peak hours implies that around 18% of the period December to March is included.[3]

3. Method overview

As presented in the introduction, the change in consumption for a specific period is defined as the observed consumption minus forecasted consumption for the same period. The forecast consists of a '"baseline" forecast, which is the average of the same period during the reference period (last five years), plus some adjustments. We chose the method partly because of transparency. As an alternative, it would have been possible to potentially increase accuracy by using a large machine learning model with consumption change as output. These results would however be very difficult to interpret, justifying a simpler and more transparent approach.

Adjustments can be made due to known "one-off" differences between the baseline and forecast periods e.g. due to new offtake connection points for large industries. It is not a trivial task to determine which adjustments to include, see below for a discussion. In Figure 1, it is shown that the load has been remarkably constant over the last 30 years, despite a population increase of more than 20% and large changes in electric consumption patterns. The projection for the near future is however a significant increase, from around 140 TWh/y today to 188 TWh/y in 2027. This is due to a "new paradigm" of electrification, mainly in transportation and industry.

[3] https://www.svk.se/siteassets/om-oss/rapporter/2022/rapport-regeringsuppdrag-dnr-i2022-02043.pdf

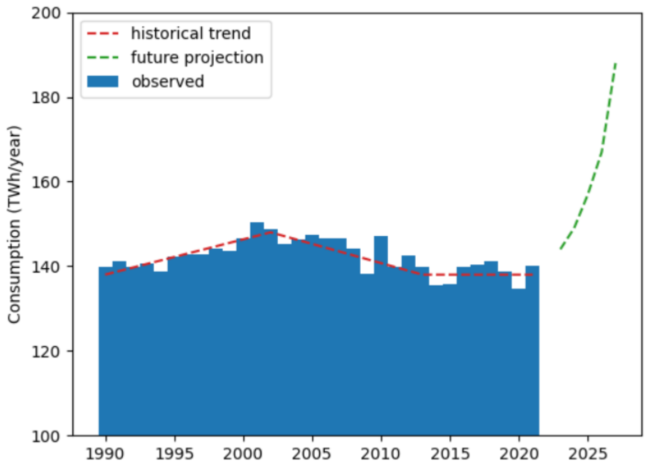

Figure 1. Historical and projected future consumption. The dashed red trend line is drawn by Svk.

Potential adjustment terms are categorized as follows:

- **Stochastic**, i.e. more or less random fluctuations around a given trend. Temperature variations[4] is the most obvious example but we also include "Corona effects" in this category (although this effect is estimated to zero, see Section 5). These are included as adjustment terms in the forecast.

- Factors contributing to the **flat trend** during the last eight years or so, e.g. population increase, digitalization, electrification and improved energy efficiency. These are not included. If one of these factors were included, all the others would also have to be included in order to not skew the results. Many of these factors are also hard to quantify.

- Factors contributing to the "**new electrification paradigm**" as described above, e.g. a new large battery factory. These are included as an adjustment factor, but only if it can be justified that they are part of the new paradigm[5].

- Actions taken because of the **energy crisis**, e.g. reduced indoor temperature and shift of consumption away from peak hours. These are obviously not included in the forecast since the aim of the analysis is to quantify exactly these load reductions.

Based on the list above, we adjust for temperature, Corona and new industries considered part of the new electrification paradigm. As will be shown in Section 5,

[4] Although the most dominant, temperature is not the only meteorological variable influencing the consumption. Potentially, one could also adjust the forecast for differences in wind speeds, humidity etc.

[5] The distinction between factors contributing to the historical flat trend and those considered part of the "new electrification paradigm" is sometimes far from obvious. As an example, the number of electric vehicles have increased during the last 10 years, but this cannot be seen in the total consumption trend and we count this as a "flat trend factor". As of Q4 2022, there are around 200,000 EVs in Sweden, corresponding to a consumption of roughly 0.5 TWh/y. If we were to increase the number to 2 million vehicles in say five years, this would imply 5 TWh/y and should probably be considered part of the new paradigm.

we estimate the Corona impact to zero which leaves us with only two adjustment terms.

As described in the previous section, only peak hours are considered. The analysis is done month by month e.g. for December 2022, the reference period consists of the December months during 2017 - 2021. The analysis is performed separately for each of the four bidding zones in Sweden (SE1-4) and subsequently, the results are aggregated for the whole country. This is because the temperature adjustment is more accurate when executed for smaller geographical regions.

Average power expressed in MW is used as the unit of measurement. The advantage of using power rather than energy is that it eliminates the need for adjustments related to differences in the number of peak hours (there might be different numbers of weekends, holidays and bridge days during different years). The final result is change in load expressed in percentage units.

Table 2 shows how the main results for a particular “analysis month” will be presented. Each column is described shortly in the bullet list below.

- **Average load last five years**: an average of consumption during peak hours in the same calendar month during the reference period. This is the baseline forecast, i.e. before any applied adjustments.
- **Temperature adjustments**: adjustments of the baseline forecast due to temperature differences. If the temperature is higher in the analysis month than during the reference period, the adjustment will be negative.
- **Electrification adjustments**: adjustments of the baseline forecast as a result of the “new electrification paradigm”, e.g. some new large industries.
- **Consumption forecast**: this column is the sum of the first three columns, i.e. baseline forecast plus adjustment terms.
- **Observed consumption**: a plain average of consumption during peak hours in the analysis month.
- **Consumption change**: observed consumption minus consumption forecast. The percentage value is calculated as load change divided by load forecast.

Table 2. Realistic but fictive example of the different terms leading to the resulting consumption change. All numbers are given in MW.

	Average consumption last five years	Temperature adjustments	Electrification adjustments	Consumption forecast	Observed consumption	Consumption change
SE1	1376	+3	+150	1529	1454	-75 (-4.9%)
SE2	2234	-37	0	2197	2088	-109 (-5.0%)
SE3	12015	-362	0	11653	10669	-984 (-8.4%)
SE4	3440	-103	0	3337	2955	-382 (-11.4%)
Sweden	19065	-499	+150	18716	17166	-1550 **(-8.3%)**

4. Temperature adjustments

The temperature has a strong influence on consumption in Sweden, in particular during the winter season. In order to make a fair assessment of the consumption change, differences in temperatures need to be taken into account. A data driven approach of temperature adjustment was chosen, using a linear regression model with temperature and calendar data as input features.

For interpretability, the model is set up so that the temperature dependence can be expressed by only one coefficient. As an example, for one bidding zone and month, the gradient found by the regression model is -220 MW/°C and the difference in mean temperatures is +1.14°C, i.e. the temperature is higher during the analysis month than during the baseline period. This means that the consumption forecast is adjusted by -220 * 1.14 = -251 MW. All data, i.e., both the reference period and the period of interest for the analysis, is used to compute the gradient.

For better (less uncertain) results, the temperature data from the ERA5 meteorological model is aggregated in both space and time. In space, the weighted average of temperature time series for each municipality in a bidding zone is taken. The weight is based on the number of inhabitants which is believed to be a good proxy for the magnitude of the temperature dependent load. It is well known that the consumption at time *t* does not only depend on the temperature at *t*, but also *t*-1, *t*-2, ... After some experimenting and optimization, the coefficients for time weighting were set to 60% of temperature at time *t* plus 40% of the average for the 72 hours before *t*. An evaluation showed that both space and time weighting (and even more the combination of the two) improved the model accuracy considerably, i.e. the magnitude of the residuals in the regression model was reduced.

In addition to temperature, dummy variables for year and hour of day were used as control variables in the regression model. Dummy variables means that one have one binary column for "hour 8", one for "hour 9" etc. The importance of using control variables is illustrated in Figure 2 below. Synthetic data for year 2021 and 2022 was generated with a true gradient of -100 MW/°C. If we regress all consumption data against temperature without using year as a dummy variable, the magnitude of the slope is not correctly estimated (underestimated in this example).

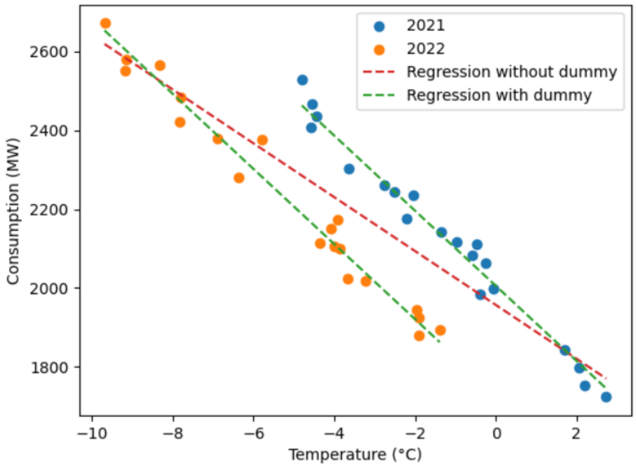

Figure 2. Synthetic example to illustrate the importance of suitable control variables (dummy variable for year in this case) in the regression model.

5. Corona adjustments

There are strong reasons to believe that reduced mobility, closed services etc. led to a reduction of consumption during the Corona pandemic. If this is the case, the forecast should be adjusted in a positive direction. To quantify the effect, a similar method as the one described in this document but with 2017-2019 as reference period was used. For example, for April 2020, a temperature adjusted forecast based on Aprils in 2017-2019 was calculated to quantify the change of consumption. The results are shown in Figure 3. We conclude that Corona clearly impacted the consumption in April to September 2020, but that the effect on the winter months (December – March) is negligible. Therefore, no adjustment is done due to Corona.

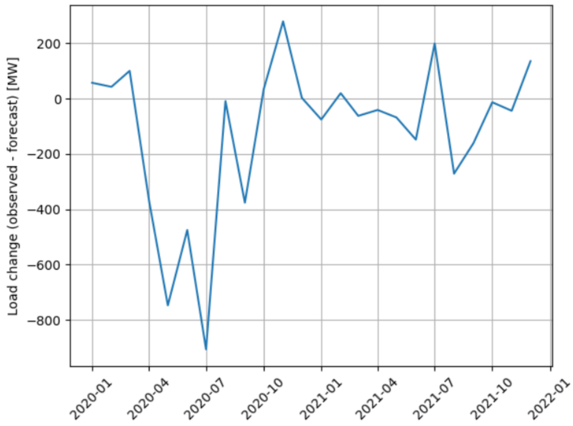

Figure 3. Estimation of "Corona effect" on electrical consumption. The forecast is based on a reference period consisting the same calendar month during 2017-2019. Note that all data was used in the computation, not only peak-load hours.

6. Adjustments due to new electrification paradigm

As discussed in Section 3, the methodology (potentially) include adjustments due to the "new electrification paradigm". Although the consumption trend has been flat over the last eight years, the near-term projection is a sharp increase; around +35% until 2027. For example, if a new "green steel" factory is built, this would imply a significant increase in electricity consumption. For a fair comparison of the consumption reduction due to the energy crisis, the estimated electricity consumption for the "green steel" factory is added to the forecast as an adjustment term.

Due to confidentiality, an explicit list of the new factories etc. is not presented, only an aggregation per bidding zone (see Table 2 for an example).