LOWERING PRICES IN A HURRY

– ELECTRICITY PRICES IN THE WAKE OF RUSSIA'S INVASION OF UKRAINE

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Lowering prices in a hurry

Electricity prices in the wake of Russia's invasion of Ukraine

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About the Team

This project was carried out by a team of researchers from Ea Analyses, Energiforsk, Energy Modelling Lab and Profu.

Project leader was Markus Wråke (Energiforsk), and analysts were Ida Græsted Jensen and Kenneth Karlsson (Energy Modelling Lab), Anders Kofoed-Wiuff, Phil Swisher and Alberto Dalla Riva (Ea Energianalyse), and Johan Holm and Thomas Unger (Profu).

The study is part of the NEPP project, with additional support from the Mistra Foundation through the Mistra Electrification project.

Key findings

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Key Findings (1)

Russia's invasion of Ukraine is the primary cause of the current Energy crisis, and electricity prices will likely remain high as long as Europe depends on natural gas for its electricity needs. This study focuses on three measures available to European citizens and decision makers in order to bring down electricity prices: reduced electricity demand, added electricity generation, and increased electricity transmission capacity.

Key findings that emerge from the analysis:

1. If no further action is taken, electricity prices in southern Sweden are likely to double during the coming winter compared the January-August average in 2022, should the weather develop as in an average year. European and Swedish electricity prices are likely to fall during 2023 but will remain higher than pre-war levels until Europe has broken its dependency on expensive natural gas for its electricity needs.

2. Saving electricity is the quickest measure available to reduce prices in the short term, with every percentage of electricity savings in Europe lowering wholesale prices in southern Sweden by around €12/MWh (17 öre/kWh for household consumers, including VAT).

   Should the proposed EU target to save 10% of total electricity use be met quickly, wholesale electricity prices in southern Sweden could fall by around €120/MWh compared with the baseline. Even if savings are limited to southern Sweden they would have significant impact, with 5% savings lowering wholesale prices there by around €28/MWh, during the winter months there.

3. Restoring production from Ringhals 4 or bringing 1 GW of mothballed generating capacity online in Sweden would likely lower prices by €15-20/MWh. The volume and dispatchability of mothballed and mainly fossil fuelled capacity is uncertain, however. Using them would also lead to higher emissions.

Key Findings (2)

Russia's invasion of Ukraine is the primary cause of the current Energy crisis, and electricity prices will likely remain high as long as Europe depends on natural gas for its electricity needs. This study focuses on three measures available to European citizens and decision makers in order to bring down electricity prices: reduced electricity demand, added electricity generation, and increased electricity transmission capacity.

Key findings that emerge from the analysis:

4. Fast-tracking renewable electricity in southern Sweden is critical for the longer term, but significant price effects will likely take 2-3 years to materialise.

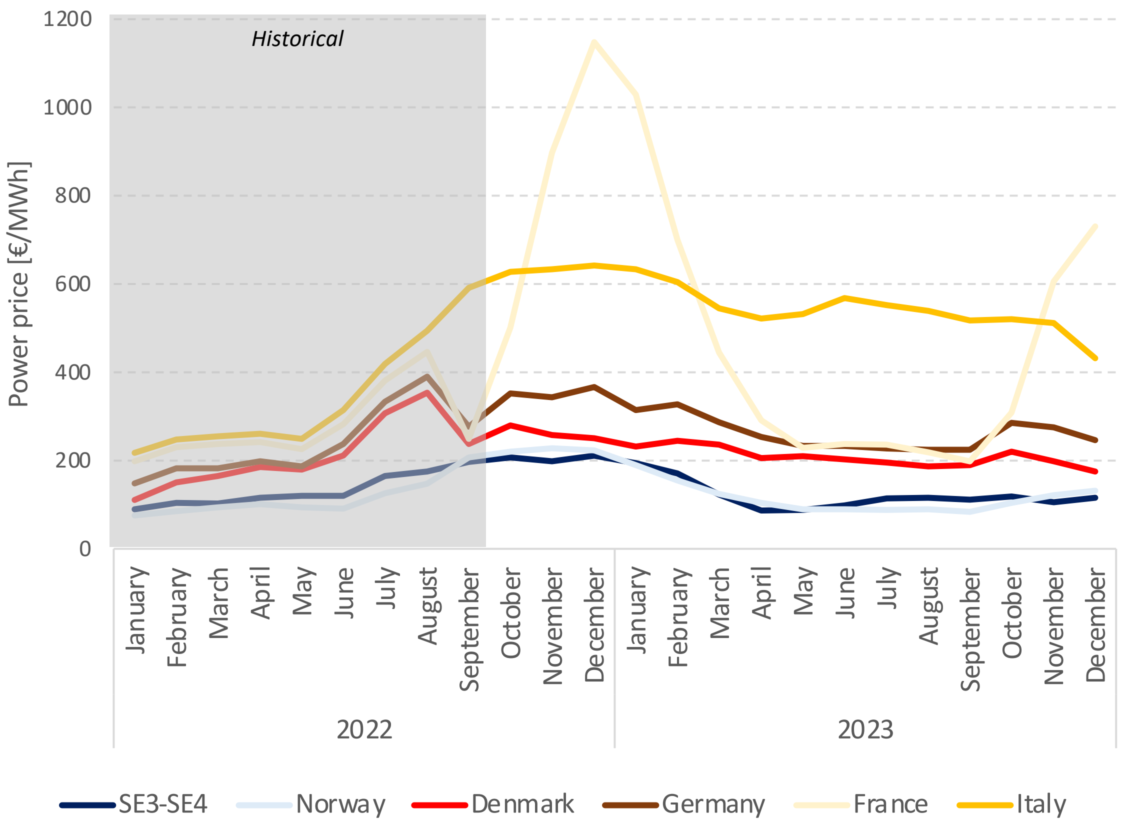
5. Increased transmission between north and south of Sweden would alleviate the situation in the south and enable higher exports of more low carbon electricity but would also raise prices significantly in the north – notably more than how much prices are lowered in the south - under current conditions.

6. The analysis suggests consumers are responding to higher electricity prices, with demand in southern Sweden falling by 4.8-6.7% in 2022 compared to 2021, but further work is needed to determine how much of this decrease emanate from other factors than demand elasticity.

Electricity prices will continue to rise during the winter 2022/23 and remain high until Europe has broken its dependency on expensive natural gas for its electricity needs

- In our baseline scenario average monthly wholesale electricity prices in southern Sweden (SE3 and SE4) rise to 150-300 €/MWh in the winter of 2022-23, with daily and hourly peak prices significantly higher.
- This corresponds to about a doubling of prices compared with January-August of 2022.
- The analysis shows electricity prices falling to around €75-125 in the baseline and continue down to more consistently below €100/MWh in 2024 and 2025. This development is largely a result of decreased natural gas prices in the baselines, consistent with current forward market prices.

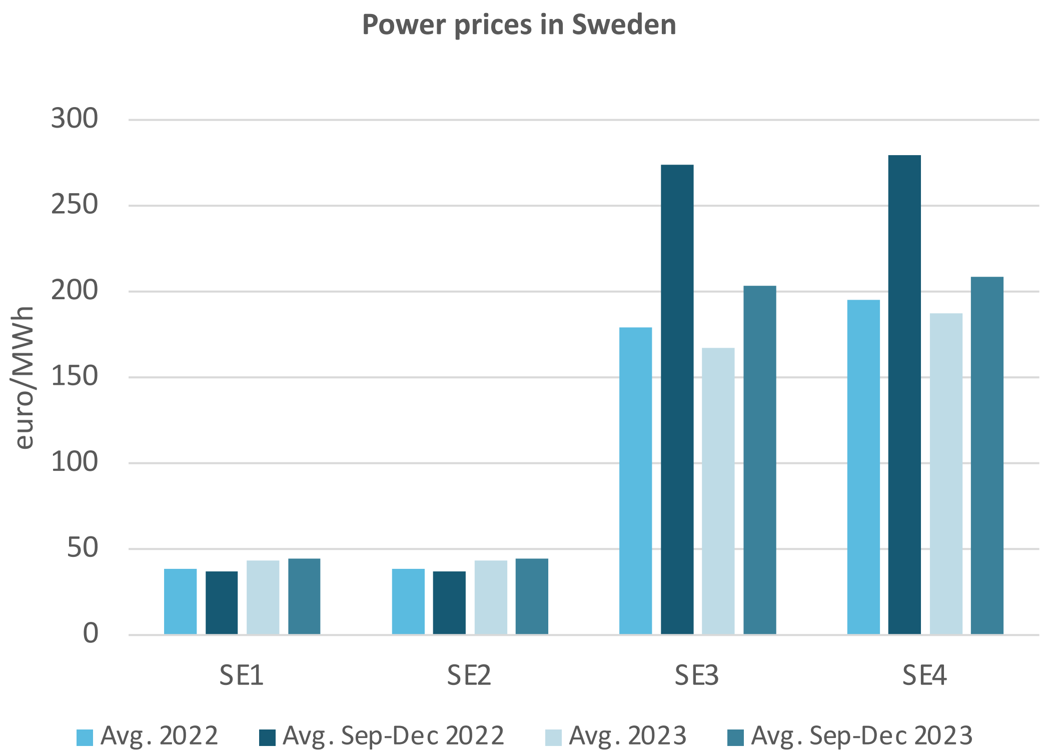
Power price projection by country



Notes: *Prices shown (historical and projection) are a 3-months rolling average. Very high prices in France reflect hours with ceiling price reached due to potential shortage of generation*

Electricity prices will continue to rise during the winter 2022/23 and remain high until Europe has broken its dependency on expensive natural gas for its electricity needs

- If natural gas prices rise further than expected, combined with a dry, cold winter with low wind, wholesale electricity prices in SE3/4 would go significantly higher. If, on the other hand, natural gas prices decrease and the winter is wet, windy and unusually warm, electricity prices in SE3/4 could come back down.
- In a scenario where natural gas prices are at tripled compared with current forward prices (to above €1 000/MWh), electricity prices in southern Sweden would rise to unprecedented levels, which are hard to model with accuracy, during about 20% of the time between September and December 2022.



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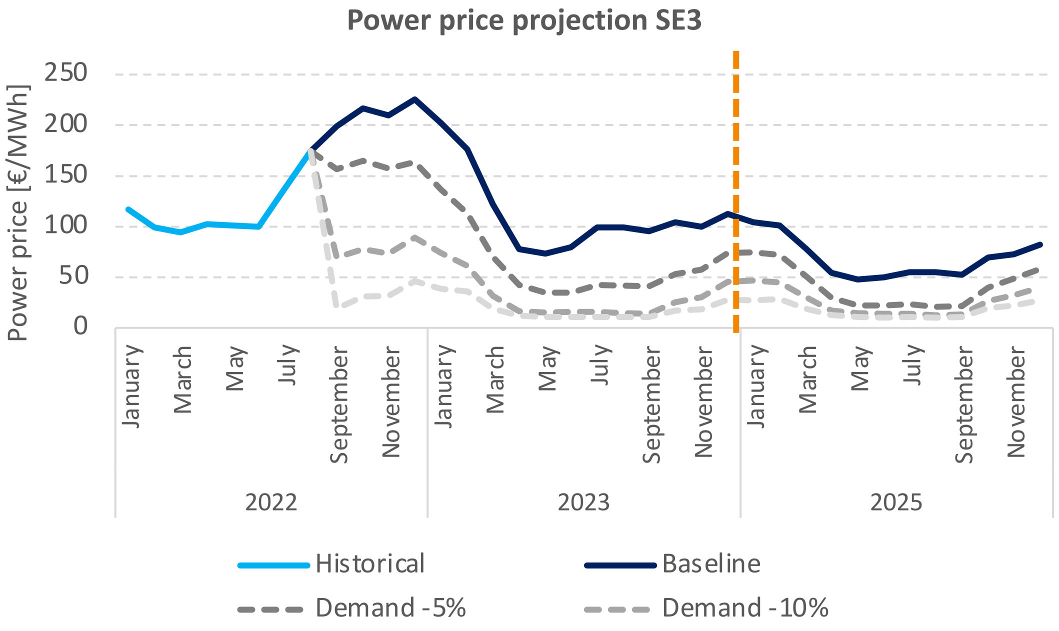
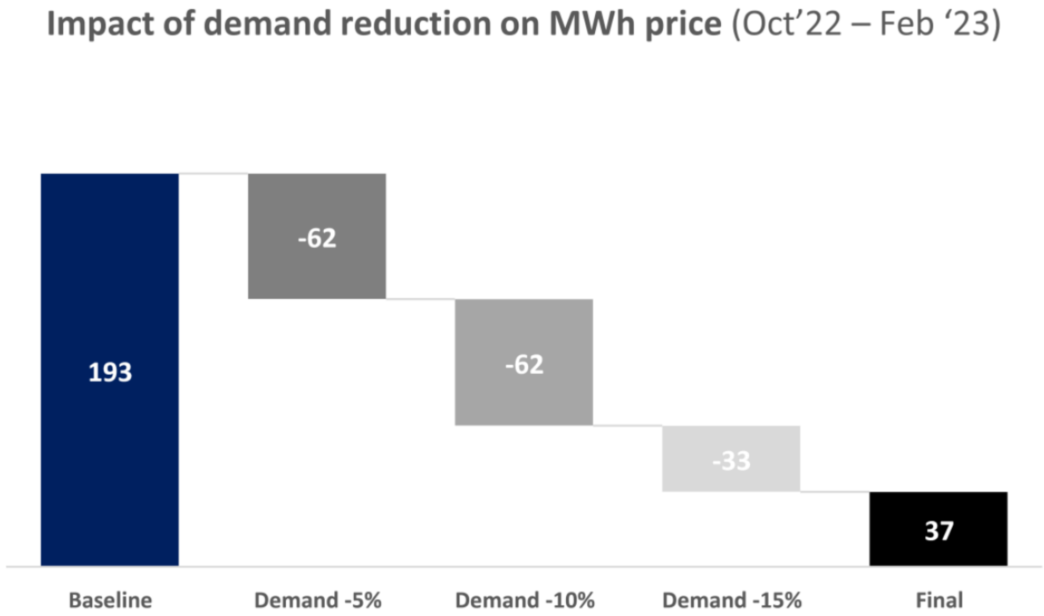
Saving electricity is the quickest measure available to significantly reduce prices, with every 1% of demand reduction across Europe lowering the electricity price in southern Sweden by 12 €/MWh

- Electricity savings would reduce consumer bills both through lower prices and less demand.
- Saving 10% of total European electricity use by March 2023, as proposed by the EU-Commission on September 15, would lower wholesale electricity prices in southern Sweden by around €120/MWh
- This corresponds to household prices being about 1:70 kr/kWh lower than what would otherwise have been the case, including VAT.
- For a household using 2000 kWh/month, this would amount to around 4 000 kr savings/month during the winter, due to a combination of reduced prices and lower consumption.



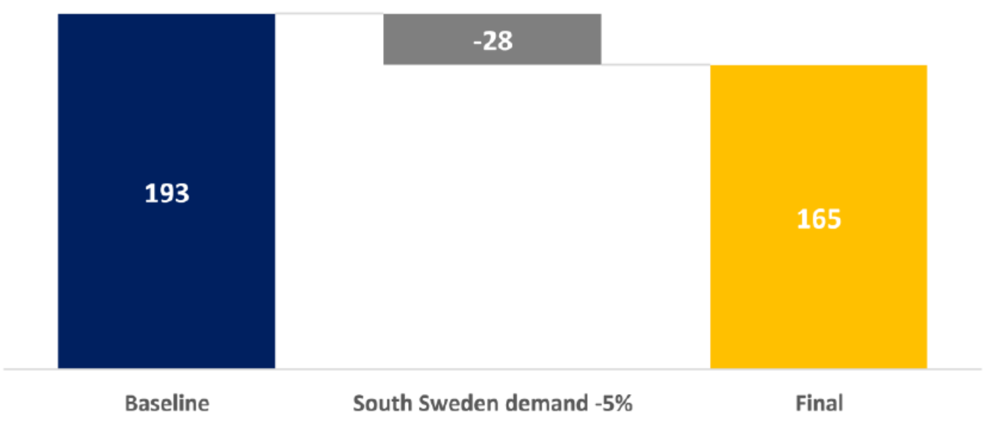


Notes: Prices shown (historical and projection) are a 3-months rolling average. The dashed vertical line indicates that simulations were made for 2022, 2023 and 2025.

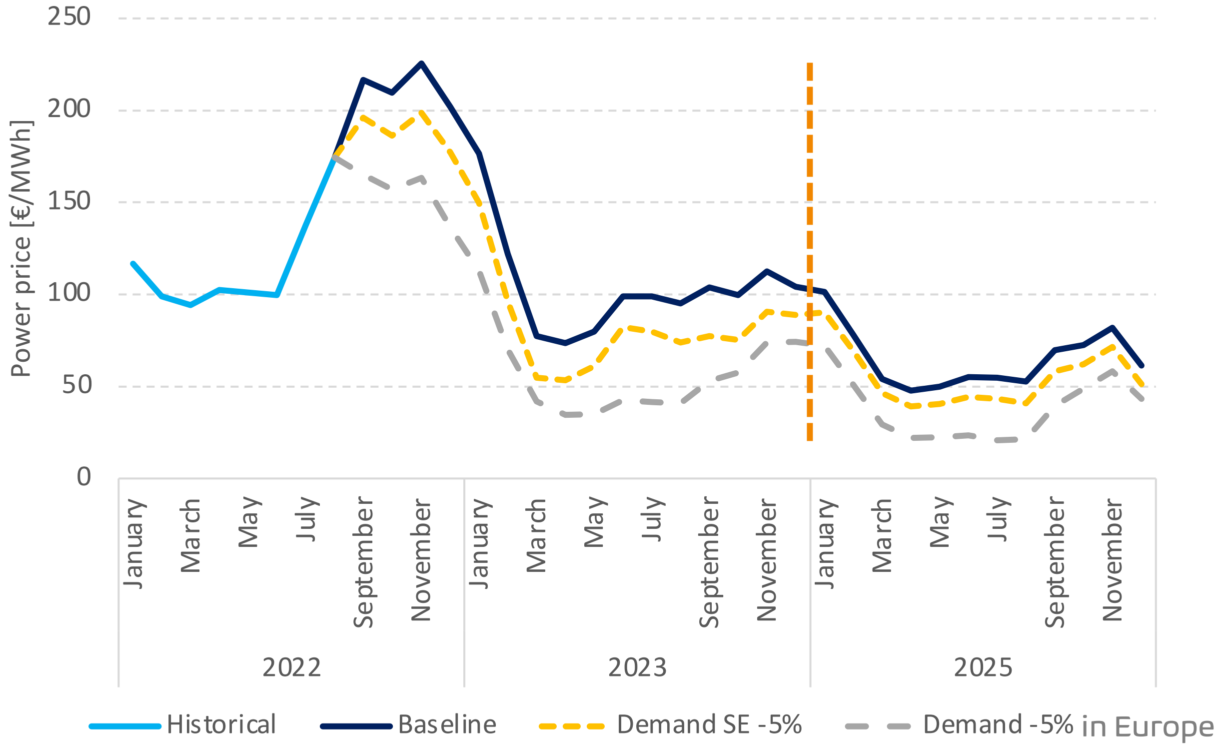
Energy savings in Sweden are not in vain, even if the rest of Europe should lag behind

- If a 5 % demand reduction happens only in SE3 and SE4 and not in the rest of Europe, the impact on prices is still significant
- Average prices throughout winter (Oct-Feb) could be reduced by 28 €/MWh (-14% compared to the baseline)

Impact of demand reduction in SE3-SE4 on MWh price
(Oct '22 – Feb '23)



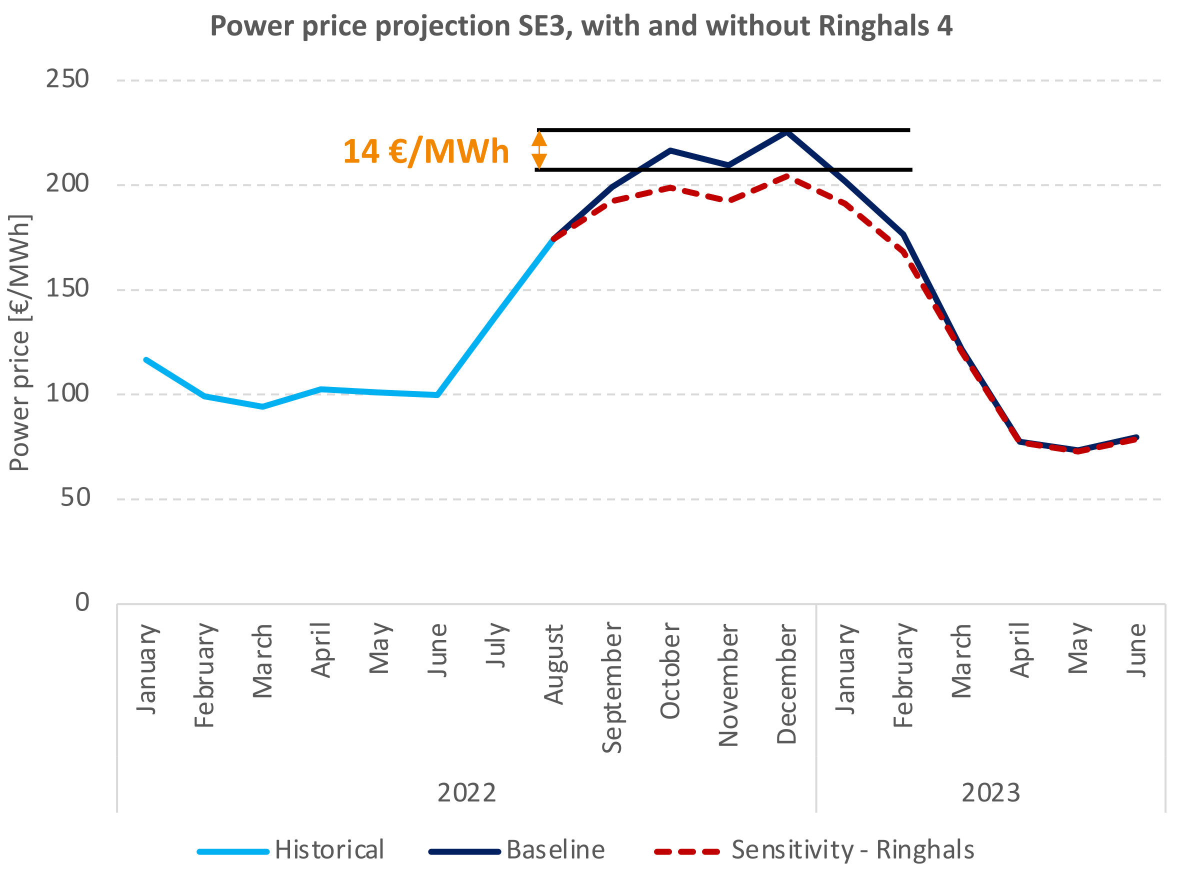
Power price projection SE3



Notes: Prices shown (historical and projection) are a 3-month rolling average. The dashed vertical line indicates that simulations were made for 2022, 2023 and 2025.

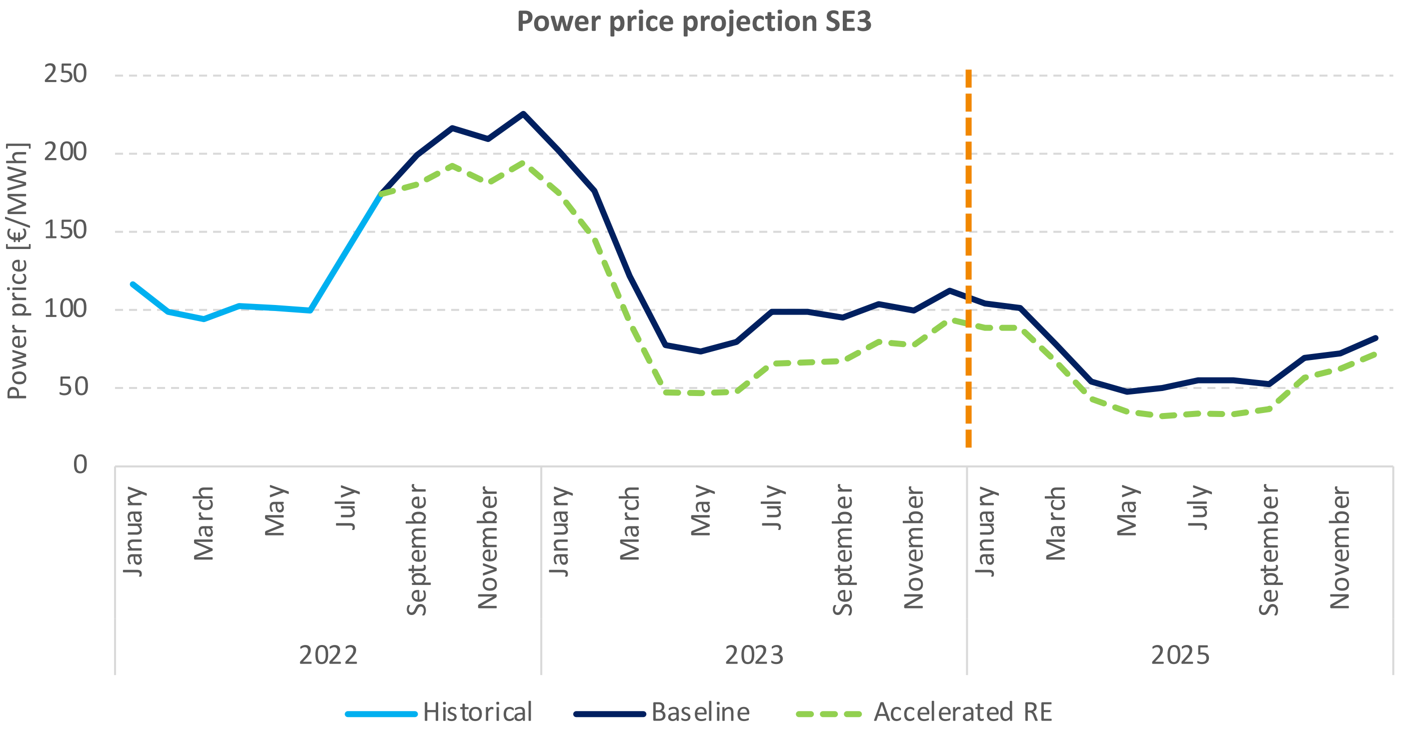
Restoring production from Ringhals 4 or bringing 1 GW of mothballed generating capacity online in Sweden could lower wholesale electricity prices in southern Sweden by €15-20/MWh

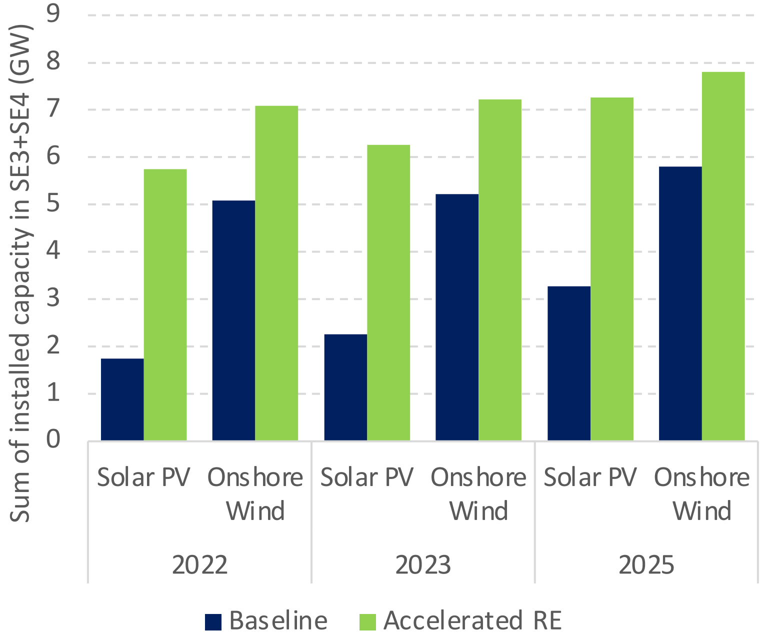
- Simulation with 1 GW of extra electricity capacity that run on heavy fuel oil indicates an electricity price reduction of ≈ 20 EUR/MWh (refers to the period Sept-Dec).
- Large uncertainty about the real availability – but a capacity of around 1 GW has been communicated from industry
- These facilities are of varying status (reserve, mothballed ...)
- Problems:
    - access to fuel (due to the status large quantities of fuel need to be obtained)
    - financing (some maintenance and other cost needs to be covered in order to make these plants operable) and
    - permits (legislative and environmental permits will in some form need to be issued or removed)
- These plants are expensive to run but with gas on the margin there is room for operating these plants
- Had the Ringhals 4 nuclear reactor come back online as planned in August 2022, as opposed to from February 2023 as in the baseline scenario, average prices in SE3 could have been around €14/MWh lower (SEK0.19/kWh for household consumers) in the period September 2022-January 2023.



Fast-tracking renewable electricity in southern Sweden is critical for the longer term, but significant price effects will likely take 2-3 years to materialise

- An accelerated RE buildout making available already this winter +2GW of wind and +4GW of solar (cumulatively in SE3 + SE4) would have a significant impact on price. Throughout this winter and 2023, having this additional RE available would have meant a price 27 €/MWh lower on average (-20%).
- The price impact is highest in summer due to weather patterns. However, building this additional RE capacity would be most likely difficult before next winter.





Notes: *Prices shown (historical and projection) are a 3-month rolling average. The dashed vertical line indicates that simulations were made for 2022, 2023 and 2025.*

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Increased transmission capacity is a priority for the south, but acts as a double-edged sword

- For electricity system stability reasons, Sweden has had to reduce access to transmission between electricity areas within Sweden but also to our neighboring countries. Reduced transmission:

  SE2→SE3

  - Installed capacity: 7 300 MW

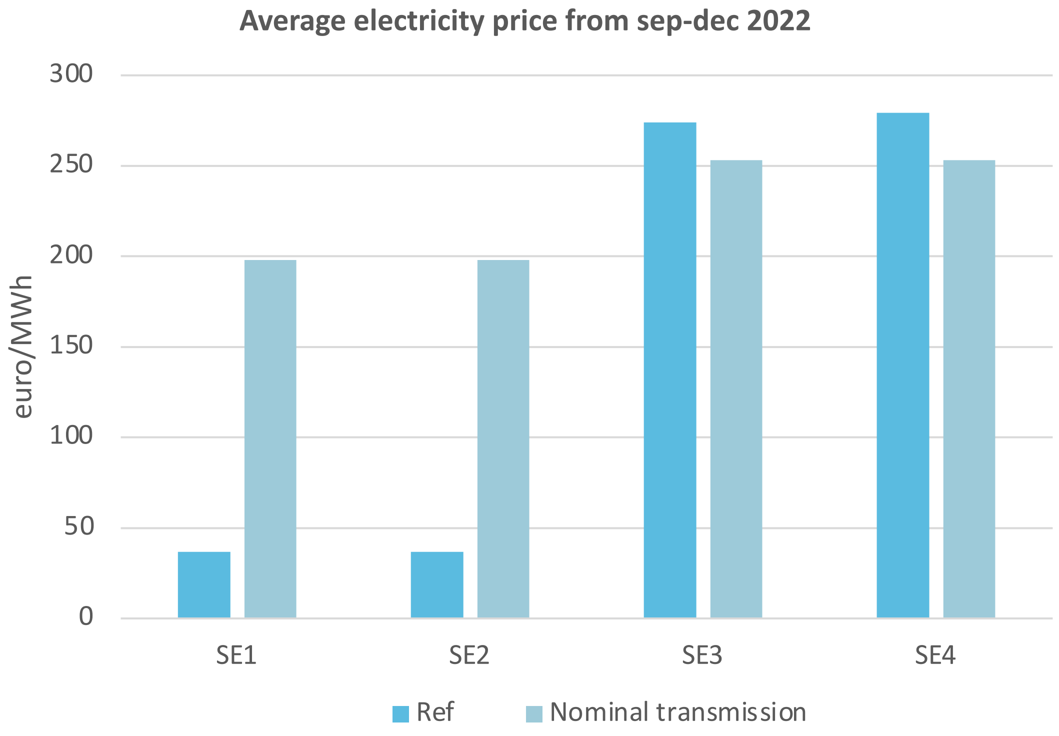
  - Average modeled capacity in reference: 6 000 MW

  SE3→SE4

  - Installed capacity: 6 200 MW

  - Average modeled capacity in reference: 4 400 MW

- Increased transmission between the north and south of Sweden would alleviate the situation in the south and enable higher exports of more low carbon electricity, but would also raise prices significantly in the north under current conditions:
- If existing transmission between northern and Sweden was used to its nominal capacity, it would reduce prices in the south (SE3/4) by around €25/MWh but raise prices in the north (SE1/2) by more than €100/MWh under current conditions in the period Sept-Dec.



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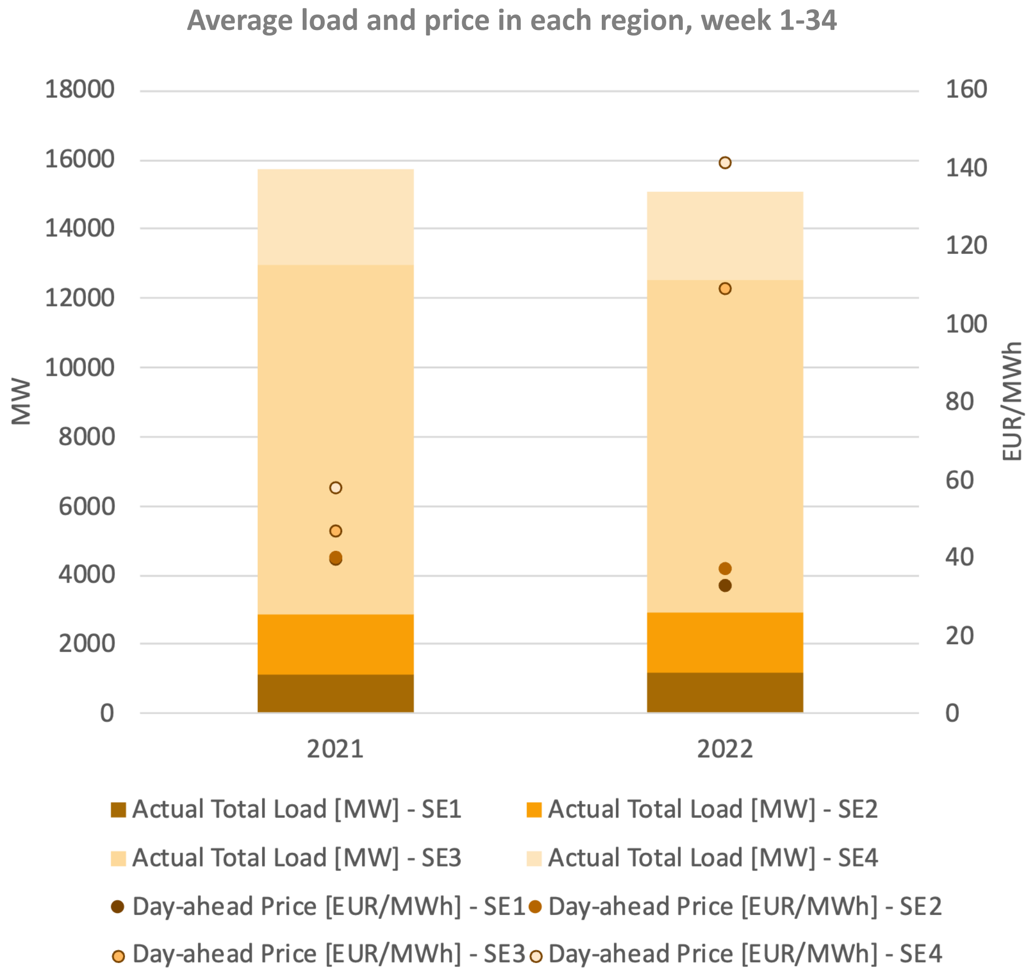
Electricity demand is falling in the south of Sweden, increasing in the north

The overall electricity load in Sweden has decreased by 4% in 2022 compared to 2021, but electricity prices and demand have developed very differently in the north and south of Sweden.

In the north, average prices were 17% (SE1) and 6% (SE2) lower in January-August than in the same period in 2021. In the same period demand increased by 5% in SE1 and remained stable in SE2.

In contrast, southern Sweden has seen dramatic price increases in 2022: 131% in SE3 and 144% in SE4. At the same time there has been a 4.8% (SE3) and 6.7% (SE4) decrease in demand.

While some of the reductions in SE3 and SE4 could be explained by fewer heating degree days and increased energy efficiency, there are also potential counter-acting factors such as more electric vehicles and increased industrial activity.



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The way forward

Saving electricity and using electricity wisely should be a priority at all levels of society. The analysis clearly shows that such savings could have a significant and quick impact on electricity prices.

Previous studies have shown that a wealth of economic savings opportunities exist in all sectors of the economy, but also that many are left unrealised. Increasing awareness and highlighting good examples would be a critical first step to unlock savings and could be done quickly. In the longer term, other actions and policies are also needed.

Utmost efforts should be made to maximise generation in existing low carbon facilities, and to secure stability of the current electricity system. Ensuring that as much of current generating capacity is kept online increase electricity supply and enables a higher utilization of transmission capacity.

In parallel, it is imperative that the deployment of new generating capacity in southern Sweden is accelerated. This will require a reversal of current trends that show the number of new permits for projects decreasing.

Finally, it is critical that decision maker do not lose sight of the longer-term priorities for the energy transition, even in this situation of crisis. Policy measures that address concerns over the economic impacts of high must be designed such that incentives for long term investments and energy efficiency are kept. Long before Russia's war on Ukraine it was clear that Europe needs to dramatically increase its investments in a suite of technologies and infrastructure necessary to reach the policy targets on climate change, energy security and competitiveness. Politicians and civil society also need to ramp up actions to further engage citizens in the ongoing energy transition. What we do now to address consequences of Russia's war on Ukraine, will have implications that may last much longer than the current crisis.

Objectives and general limitations of the study

The study aims to show which measures that are currently available to European decision makers could have an impact on electricity prices in the coming winter and in the period to 2025, and to quantify the magnitude of such price effects. It also seeks to estimate impacts of Russia's invasion of Ukraine on Swedish electricity demand to date.

The intention is to give decision makers a grasp of which measures could be most effective and how quickly impacts on prices could materialise, *everything else equal*.

Relative effects and conclusions are more robust than absolute numbers. This means the exact prices in the forecasts should be interpreted with caution. In our simulations, we have held critical factors such as weather and fossil fuel prices constant between cases in order to isolate the impact of individual measures.

For example, we have assumed that the winter 2022/2023 will be a 'normal' weather year. Should the winter turn out to be unusually warm, wet and windy, prices are likely to be lower than in the baseline scenario. But should instead the winter be unusually cold, dry and with not much wind, electricity prices could rise much higher than in our forecast.

This study has not analysed in detail whether price effects of the modelled measures are linear (i e if they have the same impact on low and high electricity prices). But all of our scenarios contain high and low price periods and results are quite consistent across the two modelling tools applied, so the findings on magnitude and relative importance of the measures should be robust.

The Annexes contain more details on methodology, assumptions and limitations of the analyses.

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Annexes

ANNEX A
Evaluation of past electricity prices and loads

Lead organization: Energy Modelling Lab

Analysts: Ida Græsted Jensen, Kenneth Karlsson

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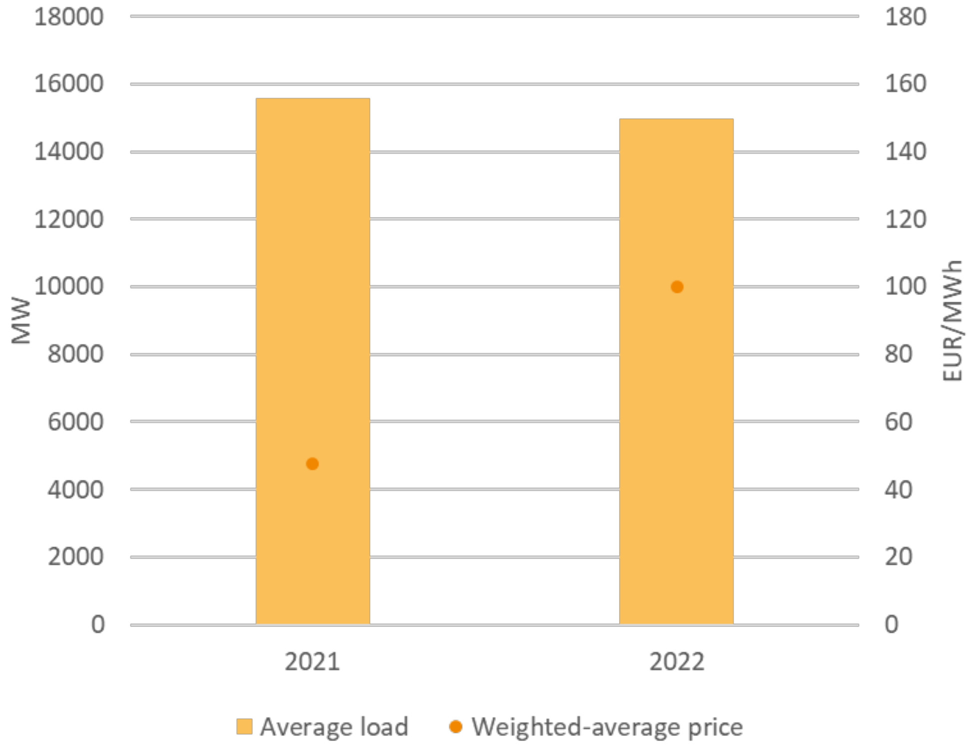
Summary

In this study, statistics on electricity prices, loads, and production types have been assessed to give an indication of the effect of rising prices on demand. Based on the data, it is possible also to quantify how much producers and the state have earned on the crisis compared to last year. At the same time, the household consumers' electricity bill have been quantified to evaluate the effect here.



The average load and weighted average price for Sweden, week 1-34

The overall load in Sweden has reduced with 4% in 2022 compared to 2021. The reduction in load can to some degree be explained by factors like fewer heating degree days and a higher energy efficiency roll-out, but at the same time also factors have driven the load the other way, e.g. more electric vehicles. The year 2022 has had high electricity prices with an increase of more than 50% on average for all of Sweden. The Southern and Central regions are the only regions where the price increase has shown. In these regions, the load is also decreasing. Even with decrease of loads, the electricity price is still high, and more seems to be necessary to reduce the total consumption.

The household consumers have paid the price of the high prices with increased costs of 1.4 billion Euros over the first six months of the year. At the same time, the state has earned on the increase of prices, as 279 million Euros extra has been paid by the household consumers for VAT and electricity tax compared to 2021.

The state can from central side reduce the electricity consumption. More campaigns can be started or regulation can be decided on. The campaigns could be focused at trying to change people's behaviour, encouraging to choose the most efficient appliances and asking industries to focus on short-term energy savings options. For regulation, an option could be to limit the amount of fixed price electricity agreements, so that people are more exposed to the variable electricity prices. Other ideas on regulation could come from Germany, where the state has made regulation lasting until end of February.

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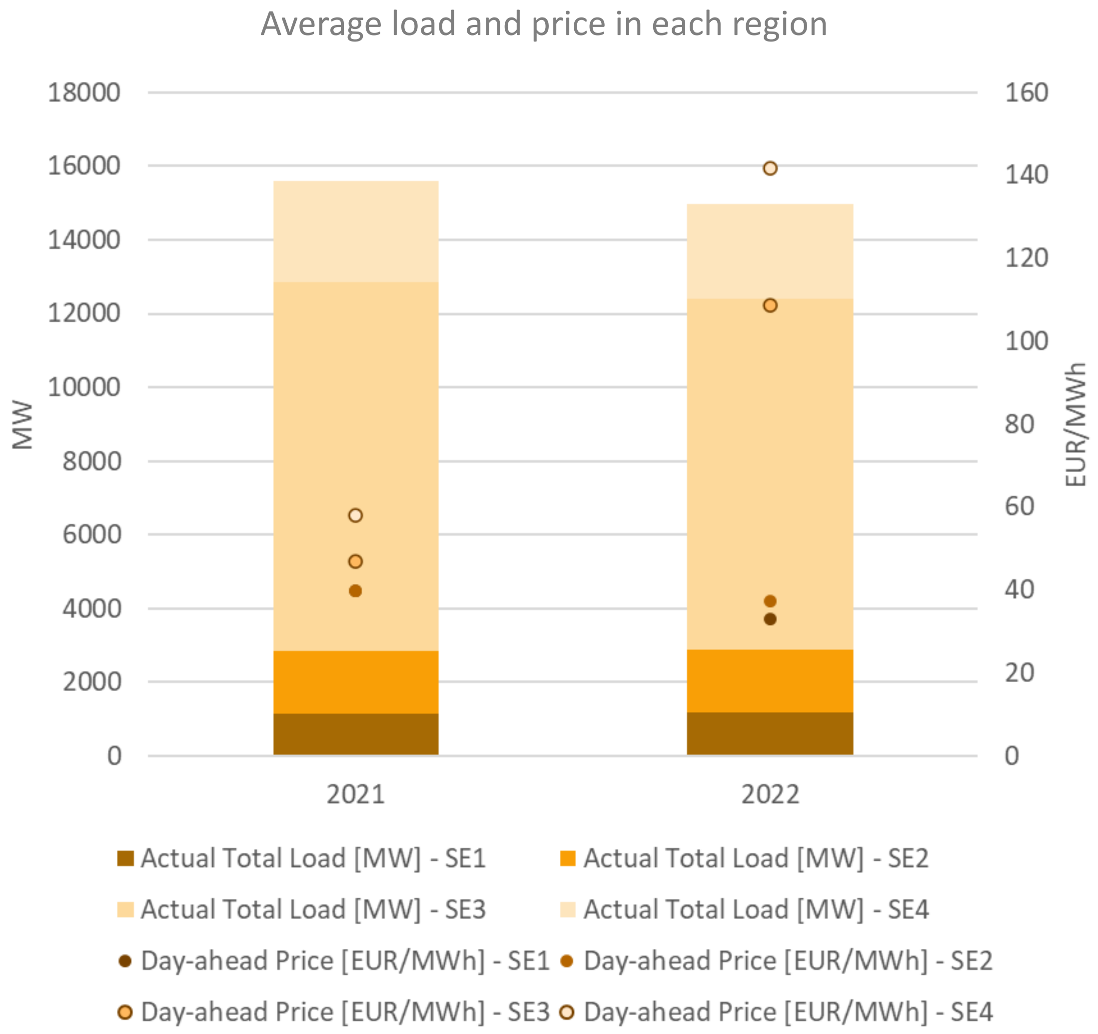
Key results 1: The impact depends on the bidding zone

The prices and demands in North and south are acting very differently. In SE1 and SE2 there has been a 17% and 6% reduction in electricity price, while the demand has increased in SE1 with 5 % and stable in SE2.

In SE3 and SE4 there has been huge increases in price with 131% and 144%, respectively. At the same time there has been a 5% and 6.5% decrease in demand.

While some of the reductions in SE3 and SE4 could be explained by fewer heating degree days and increased energy efficiency, there are also counter-acting factors as, e.g., more electric vehicles or increased industrial activity.



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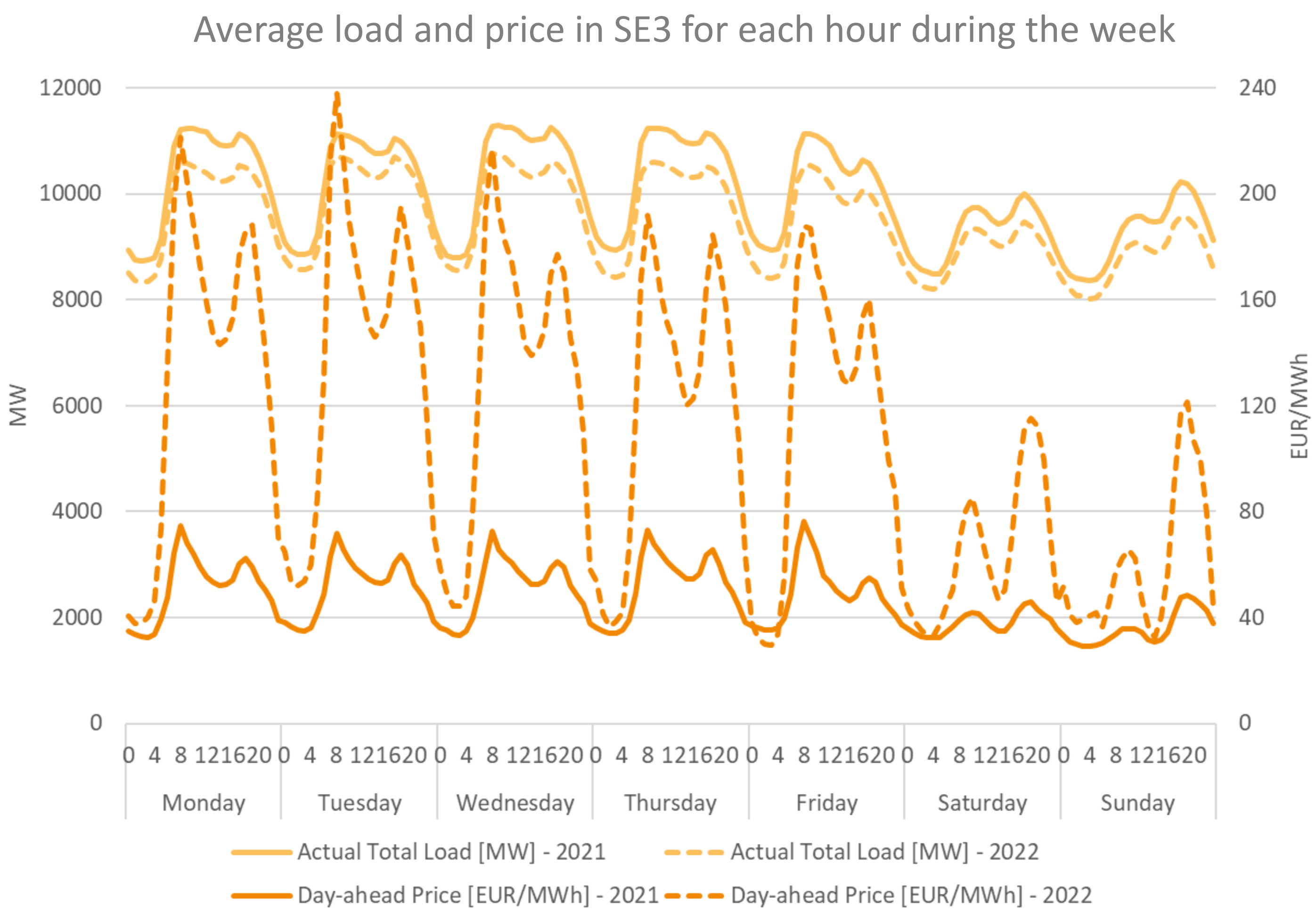
Key Results 2: More should be done to decrease the load

When considering the average of each hour during a week for SE3, the price differences shows to be highest during the day where the gas plants would produce. Even though the price in the morning peaks are up to three times higher than in 2021, the biggest effect seen is only up to 6% reduction in load.

This shows that even with very high prices, the reductions are not much higher than the average. This indicates that more must be done to further decrease the demand.



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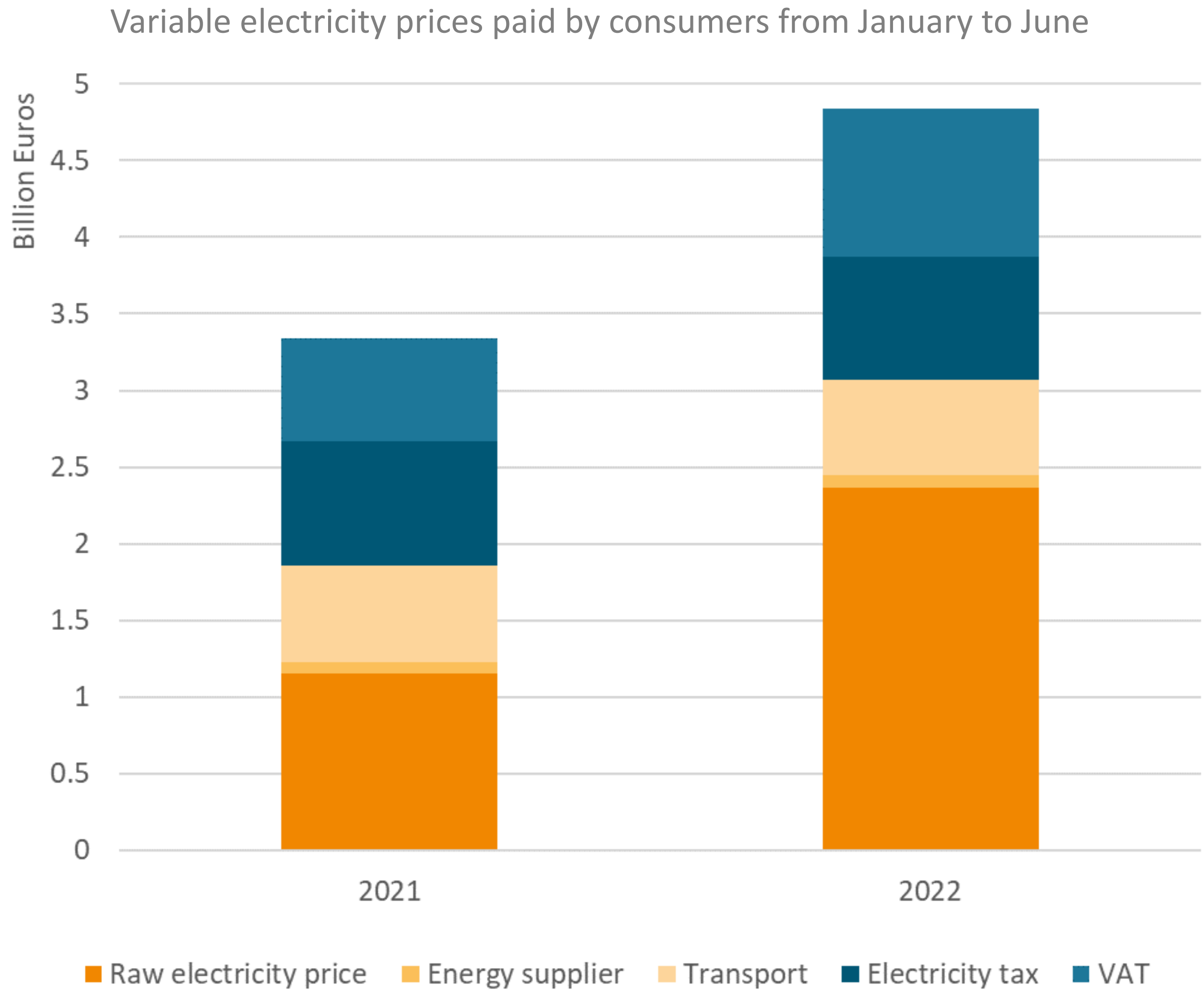
Key Results 3: The state earns money while the consumer pays the price

Assuming that a household would pay the average spot-market price, the electricity bill paid by the household consumers can be found. In the figure, only the variable part of the electricity bill is taken into account and only the electricity consumption in the first six months of the year have been used for the calculation.

The electricity bill paid by household consumers have increased with almost 1.5 billion Euros for the first 6 months. This is despite a small drop in consumption in households.

In the same period, the state have earned 291 million Euros extra on VAT and electricity tax paid by the household consumers.



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The way forward: decrease electricity consumption

Changing people's behavior

- 1°C lower indoor temperature reduces 0.9% of total electricity consumption considering only electric heated homes
- Turning off all standby functions corresponds to up to 1.4% of total electricity consumption

Encourage households to choose the most efficient appliances

- The best refrigerator uses 41% less electricity than the least efficient model on the market, washing machines 27% and dishwashers 16%

Industries should consider short-term saving options

- Better maintenance of industrial plants can save around 5% of their energy consumption
- Around 10% of energy savings implemented in European industries have less than one year payback time

Skip fixed electricity agreements

- 10-15% of electricity consumption in buildings can be shifted away from peak

Objectives and methodology

This study aims at:

- Showing how the Swedish electricity demand has changed and relating it to the increase in prices
- Identifying who is the winners and losers during the crisis

The study is carried out by analysing historical data:

- Electricity loads and prices was analysed for all regions
- Production per technology was analysed only for SE3
- All of the above data is downloaded from ENTSO-E's transparency platform. Production in 2021 showed to not be consistent with actual production (only onshore wind showed up in 2021), so the production has been downloaded from Svenska Kraftnät
- The consumption of electricity on type of use is from SCB statistikdatabasen and the split on electric heating, domestic electricity, and commercial electricity is from the Swedish Energy Agency and based on the 2019 numbers
- The price for the consumer and income for the state are calculated using energy supplier cost, transport cost, and electricity tax from https://elpriser24.se/kwh/

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Methodology: Comparison of electricity prices and loads

- The electricity prices and loads was downloaded from ENTSO-E's transparency platform.
- The above data was available until week 34 when the study started, so the analysis is based on data from week 1 to week 34.
- For the results for all of Sweden, a weighted average has been used for the electricity price, whereas the load is the sum of the average load in each region.
- When considering each region, simple averages have been used.

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Methodology: Consumer bill and state income

- The consumption of electricity on type of use is from SCB statistikdatabasen and the split on electric heating, domestic electricity, and commercial electricity is from the Swedish Energy Agency and based on the 2019 numbers.
- The consumption split on use was available with monthly values, and the last month in the statistics for 2022 was June. The analysis of the bill for the consumer is therefore only covering the first half year.
- The price for the consumer and income for the state are calculated using energy supplier cost, transport cost, and electricity tax from https://elpriser24.se/kwh/

Methodology: Calculation of effect of consumer behavior

- The calculations are based on the electricity consumption for the first six months of the year.
- The effect of a 1ºC reduction in electricity heated homes was calculated based on the assumption that this would save 5% of the used electricity. Taking into consideration the split on electricity for electric heating and domestic electricity use, the effect on total electricity consumption was calculated.
- For calculation of the effect of shutting down all standby use, the Danish Spar Energi campaign was used. Taking from here that a high use of standby functions is up to 2200 DKK/year and that the assumed price was 5.5 DKK/kWh, the electricity use per household is found to be 400 kWh/year.
- From the data on household consumption where the data from 2021 is used and under the assumption that there are 4.8 million households in Sweden, it is found that an average household consumes 4.9 MWh/year.
- Now, the percentage reduction from shutting off standby functions can be calculated to 8.2% of household consumption, and applying again the method as for heating, the effect on total electricity consumption was calculated.

Limitations of the study

- It is not possible to quantify how much of the difference in consumption comes from reduction in heating degree days, change of behaviour during corona, etc. This limits the type of conclusions that can be drawn from the key results 1 and 2, however, the need of reducing demand more is still evident.
- Statistics from the Swedish Energy Agency on split on consumers are not updated for 2021 and 2022, so assumptions on the split on type of electricity consumption (electric heating, domestic electricity, and commercial electricity) is from 2019. This would have an effect on how much the household consumers have paid.

ANNEX B
Electricity prices in the wake of Russia's invasion of Ukraine

Lead organization: EA Energianalyse

Analysts: Anders Kofoed-Wiuff, Phil Swisher, Alberto Dalla Riva

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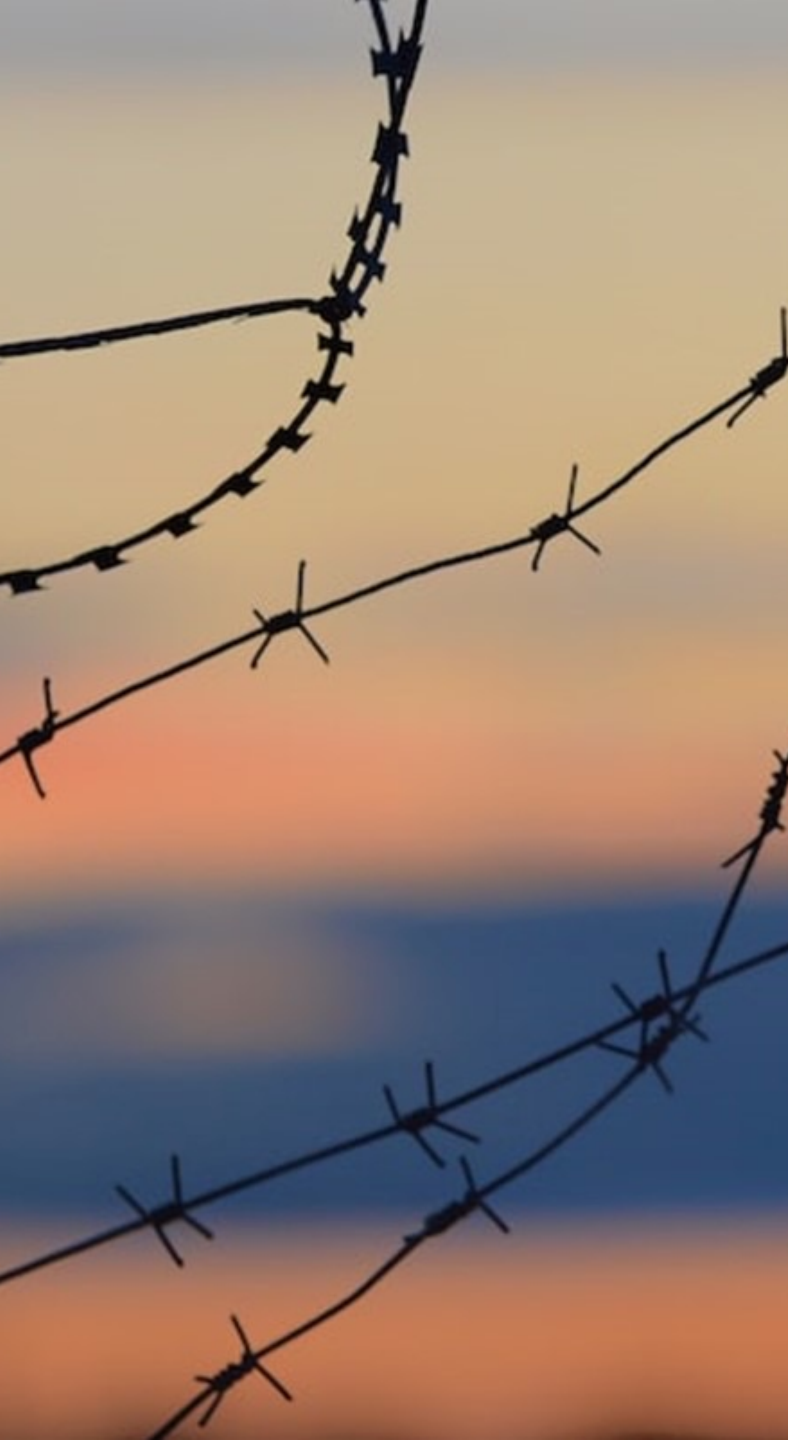

Key messages

✓Power prices in Sweden will increase further this winter to a level of **240 per MWh**, assuming gas prices follow current expectations in forward markets

✓However, **demand reductions have strong effect on Swedish power prices**, particularly if implemented across Europe (1% curbs power price by EUR 12/MWh). Even if savings are achieved only at Swedish level, the price decrease is still around 14% (vs 32%).

✓The **price effect from wind/solar capacity additions in Sweden is significant** with an average price reduction in 2022-23 of 27 €/MWh (20% price reduction). However, probably difficult to speed up deployment before next winter.

✓Gas to coal fuel shift due to crisis cause European CO2-emissions to increase by about 145 Mt in 2022, but combined with a 10% demand reduction, emissions can be **brought back to pre-crisis levels**.

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The analysis focuses on projecting power prices towards 2025 with focus on Europe

- An analysis with the **power system model Balmorel** is carried out, optimizing dispatch for the years 2022, 2023 and 2025
- Optimization of **power plant dispatch** and replication of day-ahead power price formation. One of the key output is **power price projection**, depending on input and scenario assumptions.
- **Geographical scope** covers not only the Nordic countries, represented with all Nord pool bidding zones, but also the Baltics, Germany, UK, France, Italy and other countries in continental and West Europe *(see figure)*

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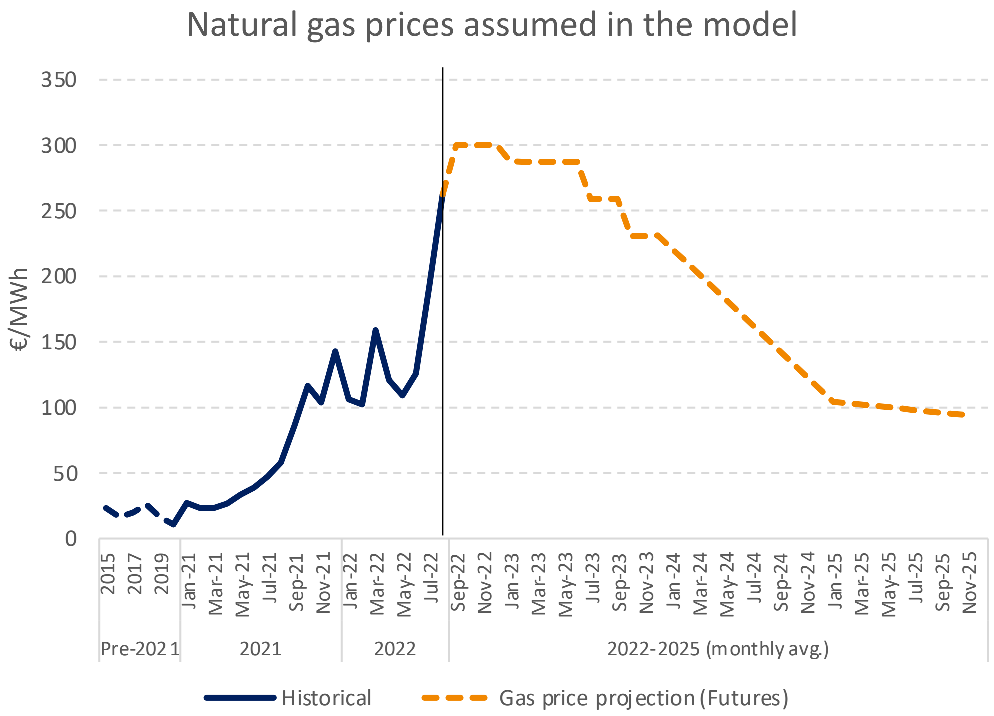
Key recent developments affecting power prices are considered

- **Fossil fuel prices**, in particular natural gas price have been recently skyrocketing following the uncertainty related to Russian gas supply to Europe: TTF futures as of end of August considered.
- Current meteorological conditions, in particular the **dry year for hydropower** in the Nordics (90% inflow compared to normal year) and in Europe (83% of normal inflow).
- Current installed generation and transmission capacities.
- Situation of nuclear power plants: **low availability of French nuclear** (25% less than historically) and **Ringhals 4** (Sweden) offline until end of January 2023.



- Limitation of coal plants use: **coal has not been largely reactivated** across Europe despite the soaring gas prices, due to a combination of political and technical factors. We limit the coal use in 2022 in France (3.9 TWh), Germany (70 TWh), Italy (~22TWh) and UK (6.6 TWh).

Scenario analysis to shed light on key uncertainties

- How will **power price evolve** in Sweden (SE-3 and SE-4) the coming winter and towards 2025?
- What **price level** will be settled across the European power market?
- What could be the impact on price levels of potential measures to alleviate price pressure
  - **Power demand reduction** measures (across EU or Sweden)
  - Release installed coal power capacity in main countries (UK, Germany, France, Italy)
  - Acceleration of wind and solar buildout in Sweden

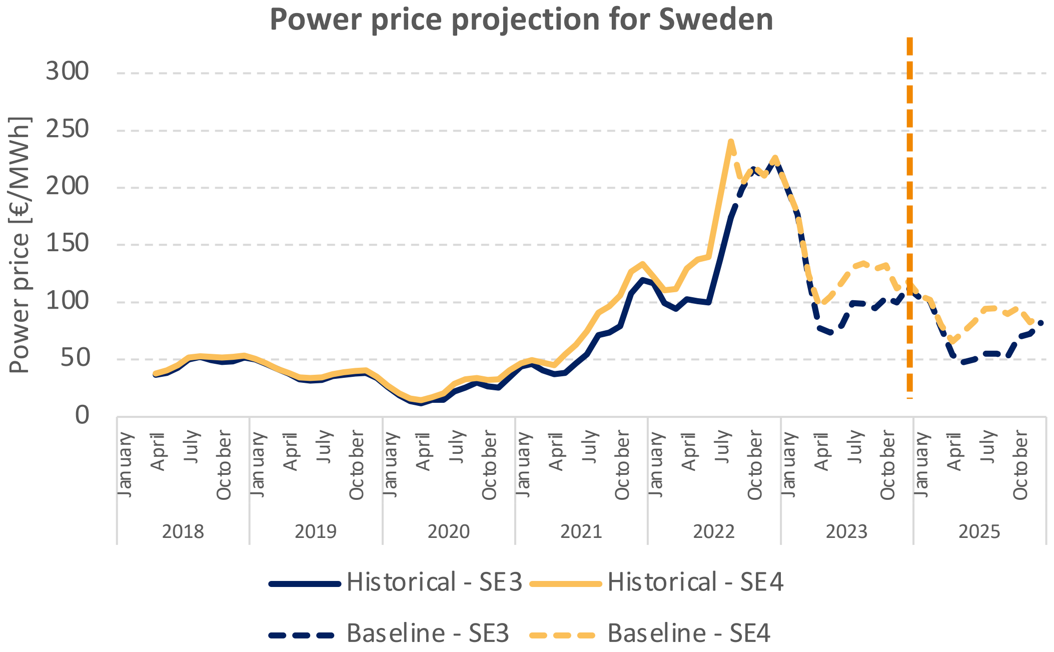
Baseline scenario

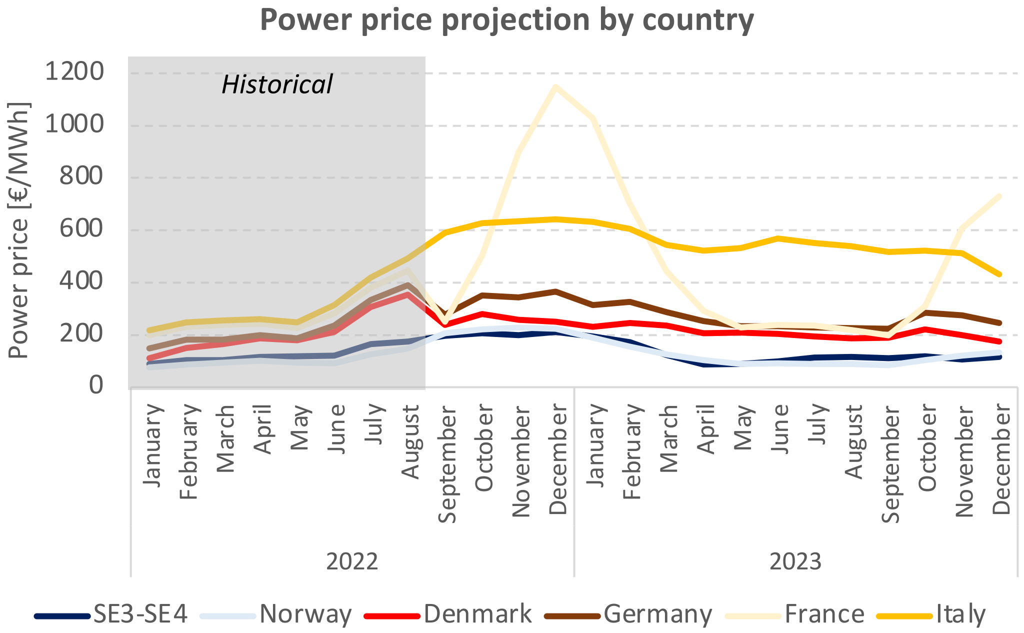
EU demand -5%, -10%, -15%	*Reduction of gross power demand in all modelled countries in EU of 5, 10 and 15%*
SE Demand -5%	*Reduction of gross power demand in SE-3 and SE-4 of 5%*
SE accelerated RE	*Additional RE buildout of +1GW of wind and +2GW of solar in both SE-3 and SE-4*
Unrestricted coal	*Removal of coal use restriction in France, UK, Italy and Germany. All installed capacity can be used*
Sensitivity: Ringhals Unit 4	*Ringhals Unit 4 comes back online after summer as normal and stays online throughout winter*

In the Baseline, prices remains high over winter

- Power prices in SE3 and SE4 are expected to continue to hike through winter 2022
- Prices spikes at 240 €/MWh, but revolves around or below 100 €/MWh for the rest of 2023 and 2025

- Modelled winter prices stay at summer levels in DE, as part of generation is assumed to switch to coal
- Norway and Sweden are expected to maintain lower prices compared to the rest of Europe





***Notes:** Prices shown (historical and projection) are a 3-month rolling averages. Very high prices in France reflect hours with ceiling price reached due to potential shortage of generation. The dashed vertical line indicates that simulations were made for 2022, 2023 and 2025.*

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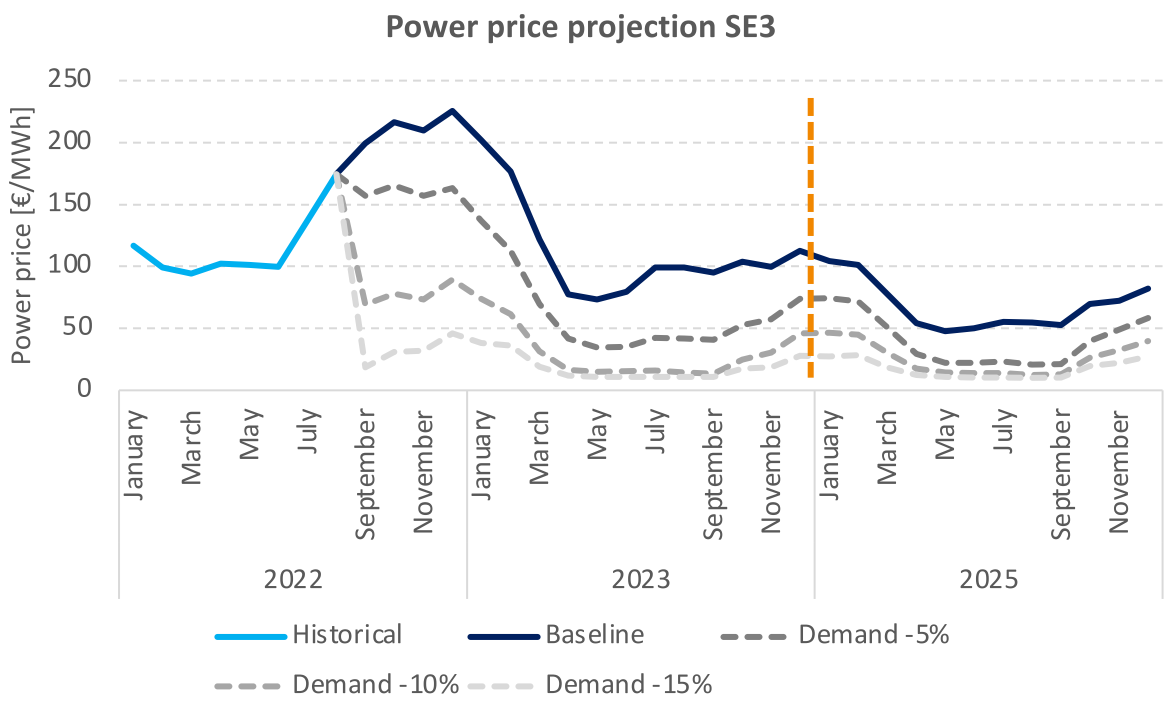
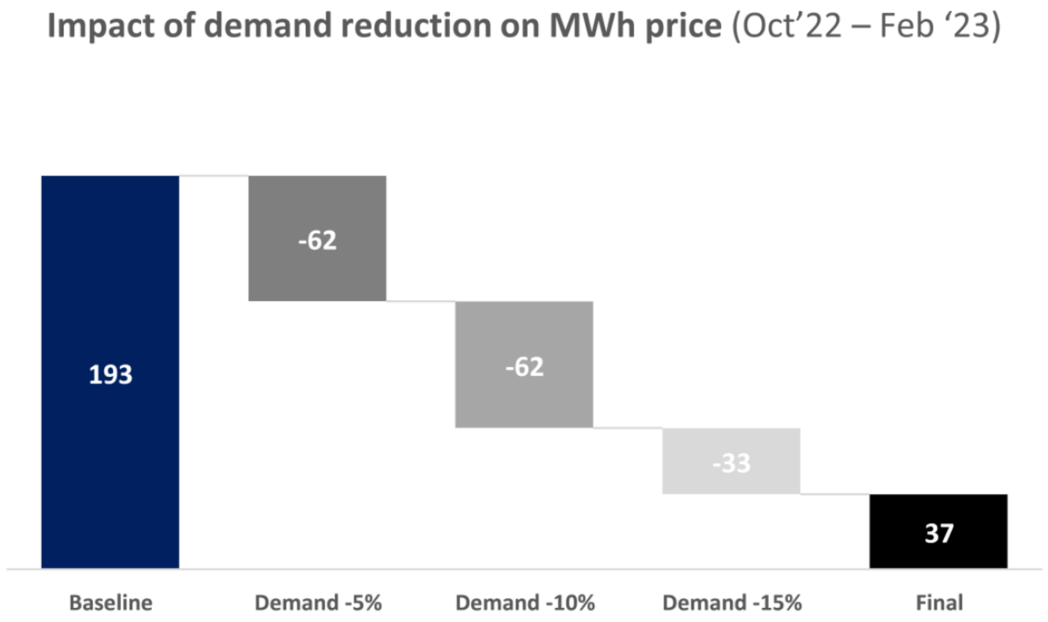
For every 1% of demand reduction across Europe, the electricity price southern Sweden is reduced 12 €/MWh

- Reducing the power demand across Europe has dramatic impact on the price development
- A reduction of 5% of demand in all Europe this winter correspond to a 32% reduction in price in SE3 (62 €/MWh less). A further 5% reduction in demand yields similar effect on price in absolute terms. Almost the same effect is seen in SE4.



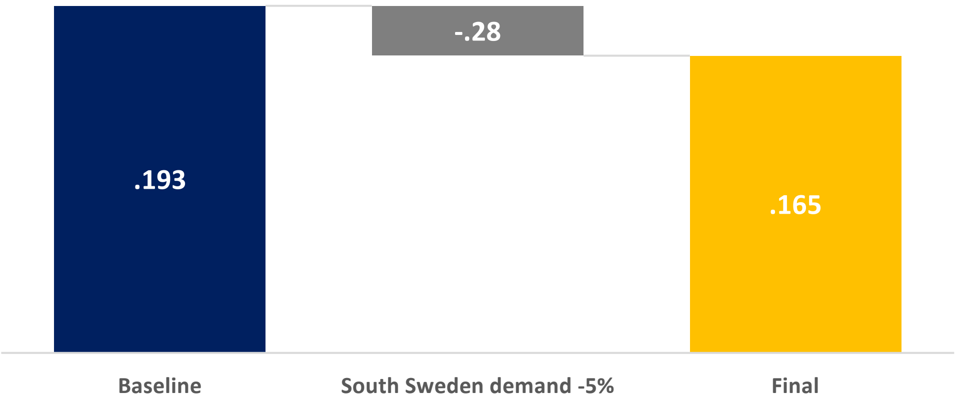


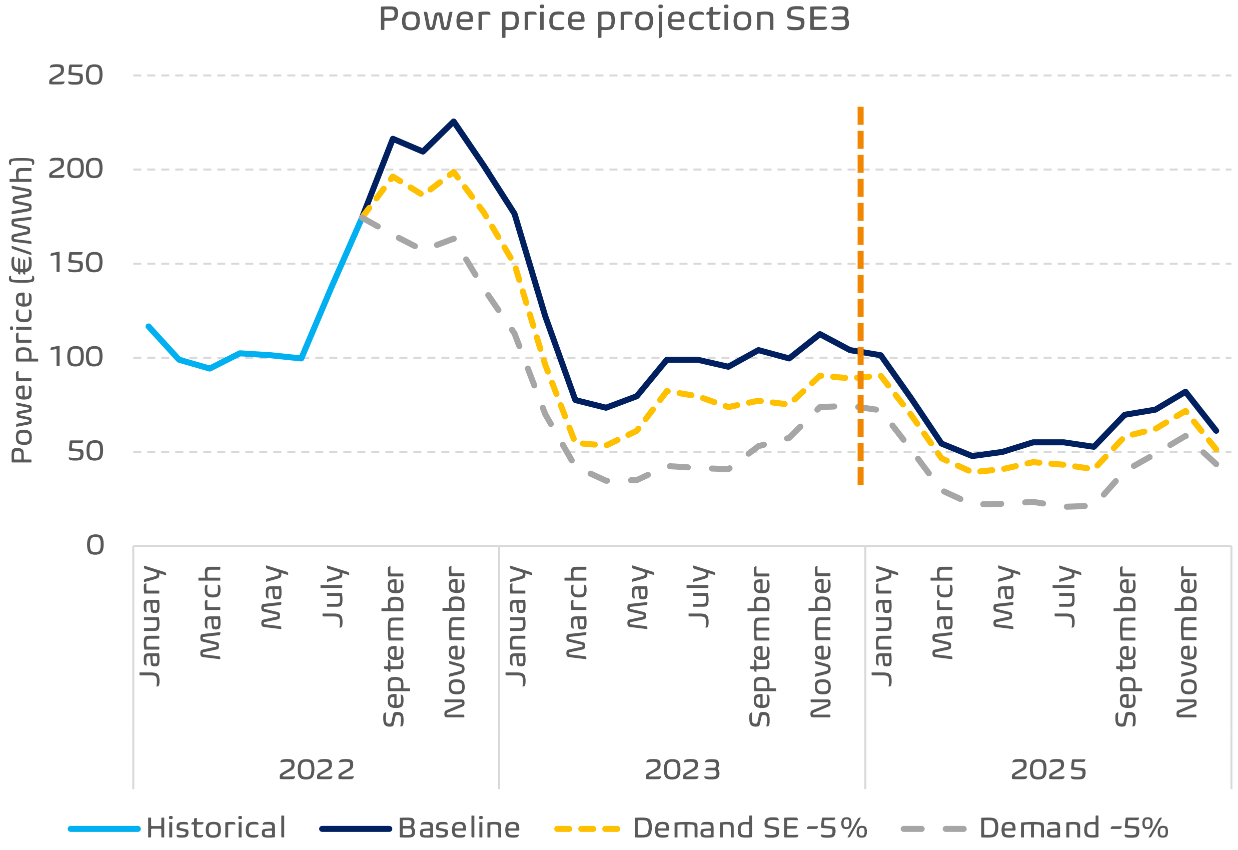
Notes: Prices shown (historical and projection) are a 3-month rolling average. The dashed vertical line indicates that simulations were made for 2022, 2023 and 2025.

Even if only Sweden reduces demand, the price can be impacted 14% downwards

- If a 5 % demand reduction happens only in SE3 and SE4 and not in the rest of Europe, the impact on prices is still significant
- Average prices throughout winter (Oct-Feb) could be **reduced by 28 €/MWh** (-14%)

Impact of demand reduction in SE3-SE4 on MWh price
(Oct ’22 – Feb ‘23)





Notes: Prices shown (historical and projection) are a 3-months rolling average.

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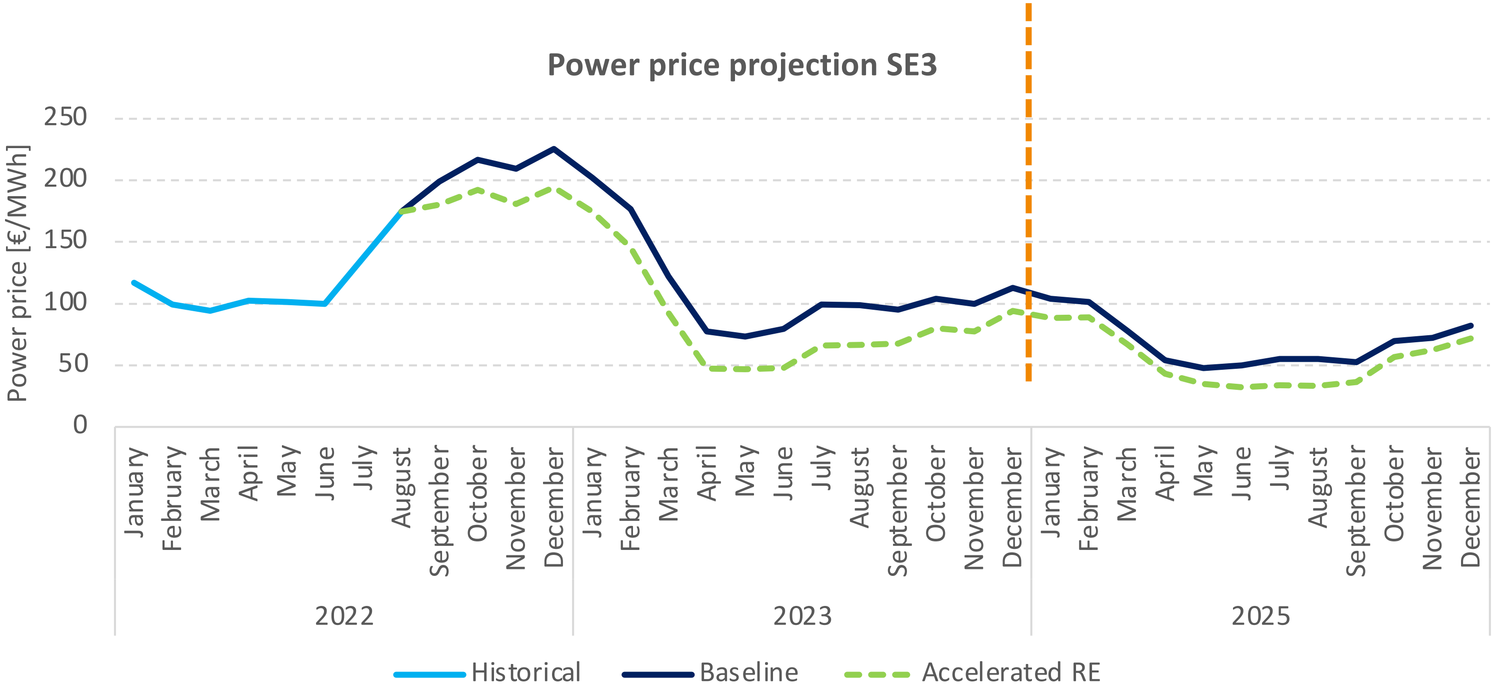
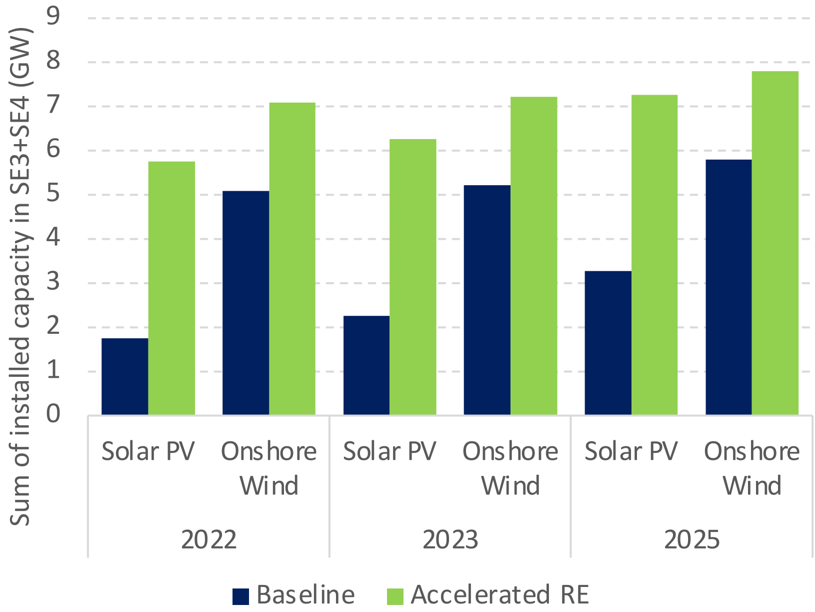
Higher RE buildout in SE3 and SE4 bring significant price reduction, but would not help in the upcoming winter

- An accelerated RE buildout making available already this winter **+2GW of wind and +4GW of solar** (cumulatively in SE3 + SE4) would have a significant impact on price. Throughout this winter and 2023, having this additional RE available would have meant a **price 27 €/MWh lower on average** (-20%).
- The **price impact is highest in summer** due to weather patterns. However, building this additional RE capacity would be most likely difficult before next winter.





***Notes:** Prices shown (historical and projection) are a 3-months rolling average.*

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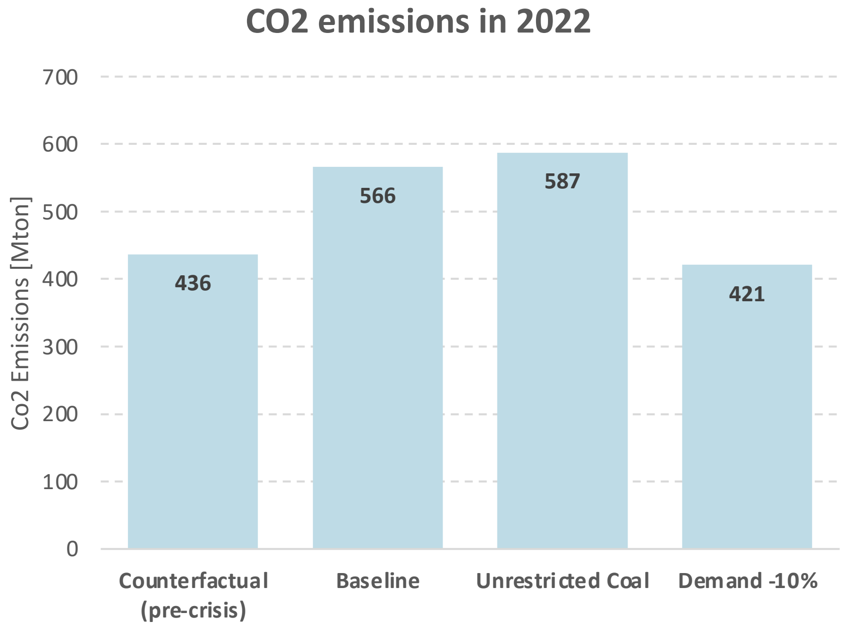
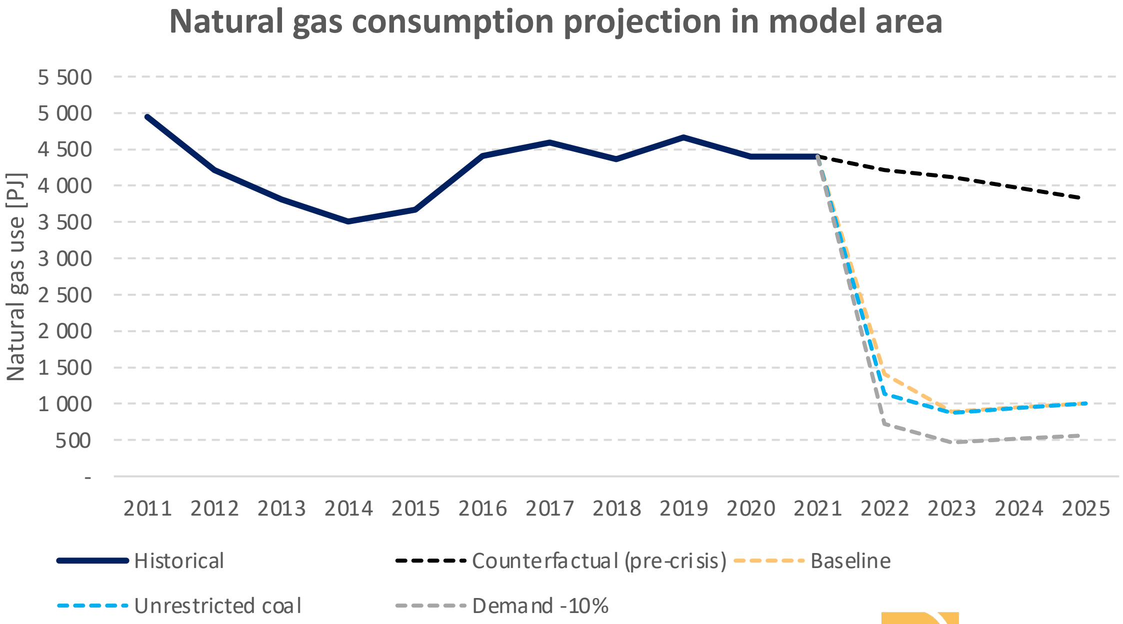
Reducing demand is the most effective way to curb emissions and gas dependency

- All scenarios result in a **large decrease in gas use compared to both historical data and a counterfactual case** assuming pre-crisis gas prices in 2022. At the same time CO_2-emissions related to electricity production increase by 130 Mt (30%) at the European level as coal and lignite replace gas.
- Allowing coal capacity to be used without restrictions increase emissions further by 21 Mtons (+4%) in 2022, and pushes gas demand further down.
- 10% demand reduction can bring emissions will **back to pre-crisis levels**.
- *Note: Results regarding gas consumption need be interpreted with caution since there is a significant uncertainty regarding the availability of coal fired generation capacity for the coming winter in several European countries. Therefore, coal-fired capacity may turn out be more restricted than assumed in the baseline case due to, among other things, regulatory limitations .*





***Notes:** 2024 in the Gas use graph is an average between 2023 and 2025 (simulated years)*

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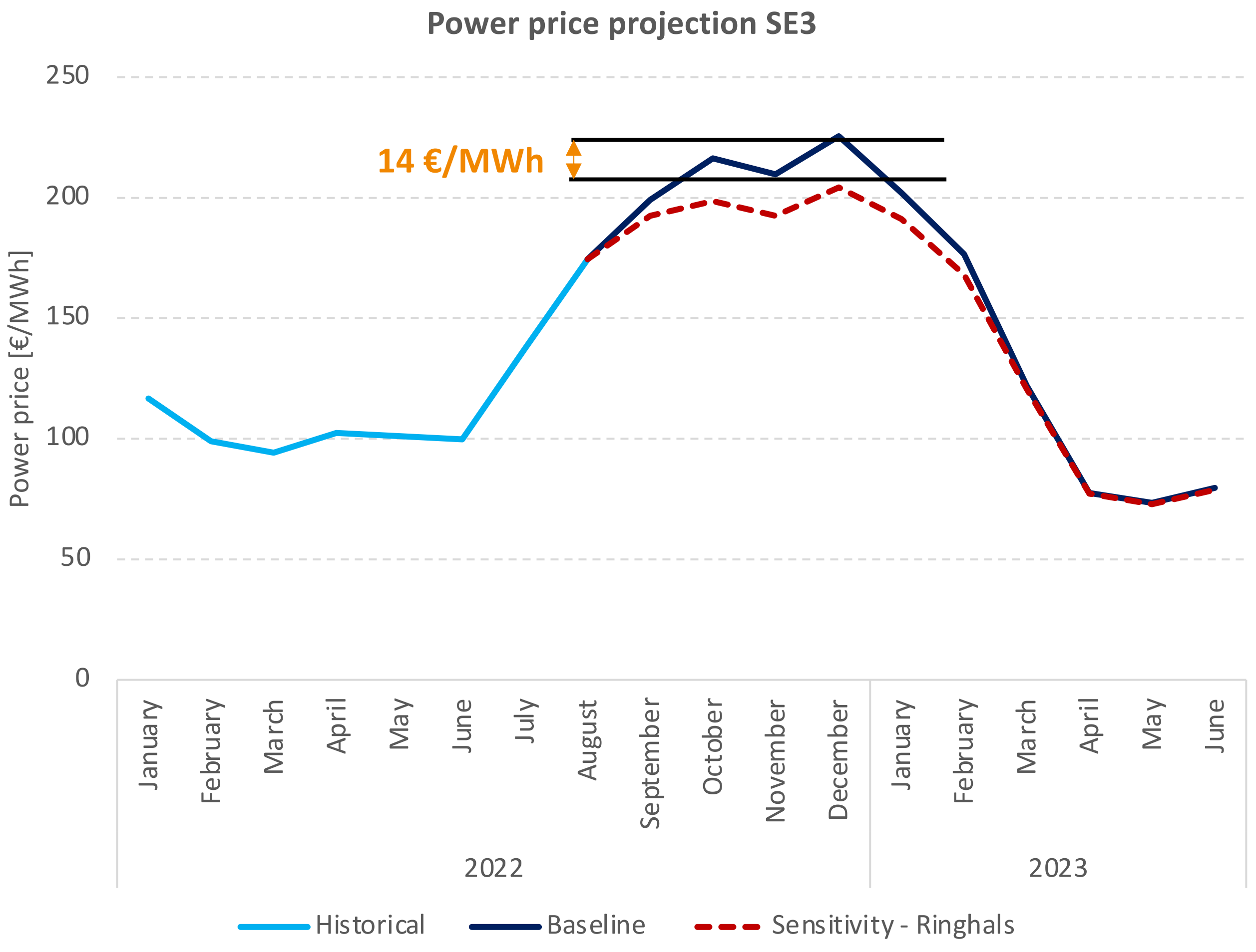
Sensitivity: Ringhals Unit 4 can guarantee a power price reduction of 14 €/MWh this winter

- The sensitivity on Ringhals assumes that after summer 2022 Unit 4 (1.100 MW) gets back online as in a normal year, while in Baseline the plant is back in February 2023

- The presence of Ringhals Unit 4 during the winter **reduces prices by an average of 14 €/MWh** in the period September-January, corresponding to a 7% price reduction



Notes: *Prices shown (historical and projection) are a 3-months rolling average.*

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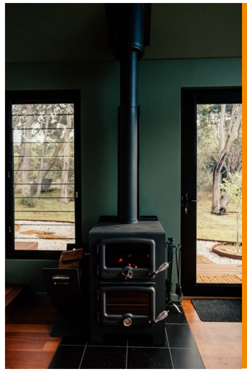
Reservations and uncertainties

Modelled vs real world

Modelling of large and highly complex systems as the European power systems relies on availability of data and knowledge on many levels. While a calibration exercise have been carried out based on available statistics, as even the statistics come at a high level of uncertainty and often at an aggregated level. For example, data on the capacity of coal power plants is available, but not on the operational state or condition of each plant. While e.g. coal units have been derated and constrainted to represent assumed physical/regulatory constraints, it may be that some plants operate in the model at quantities that is not physically possible to maintain. To the extend that the modelled units – mainly coal and oil units – for any given reason are not capable of running at the capacity factors achieved in the model, the marginal in most cases is natural gas and would lead to increased gas reliance and electricity prices.



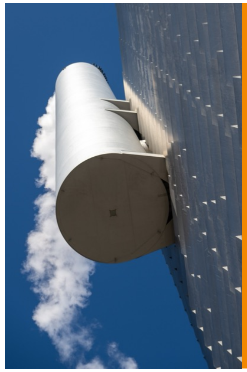
Demand elasticity

A conservative approach to modeling demand elasticity has been applied. The model is forced to satisfy all demand at all times, with limited options for demand shifting. Demand elasticity could play a significant role when electricity prices reaches a certain threshold.

Price adaptive demand-side dynamics not represented in the model will have an alleviating effect on the electricity prices.

Weather year

2022 is considered a dry-year in the modelling. Apart from that the demand and RES quantities in the model are based on normal climate years. Hydro reservoir levels, wind and solar availability and heat and cooling demands etc. are sensitive to changing weather conditions. A cold winter or low wind or hydro availability will result in a higher reliance on thermal power resulting in higher gas reliance and electricity prices than found in the present simulations.



Fuel prices

The fuel and EU ETS prices are modelled deterministically and do not include any supply/demand feedback on the prices in the model. In the case of insufficient margin in global coal and oil supply to meet the additional demand identified in the model, a price increase could be expected beyond what is captured in the forward prices that have been applied in the model.

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Balmorel: Energy system model

Power, heat, H2 demands

Fuel prices, Taxes and subsidies

Technology data (cost, efficiency, etc)

Weather data

EV

Heat

Power

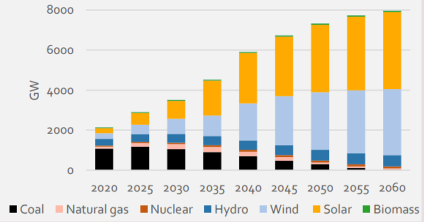
H2

BALMOREL
Energy system model

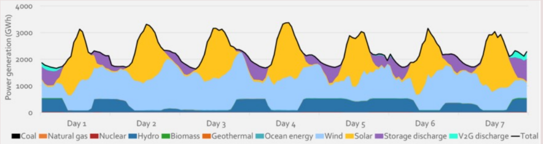
Long-term expansion

Short-term dispatch

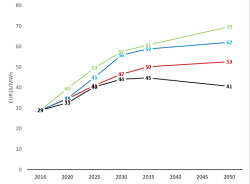
Optimal expansion generation and transmission

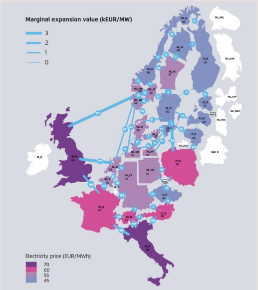


Detailed dispatch information

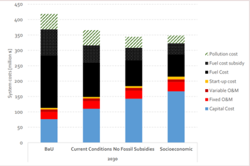


Electricity prices and plant revenues





CO2 Emissions



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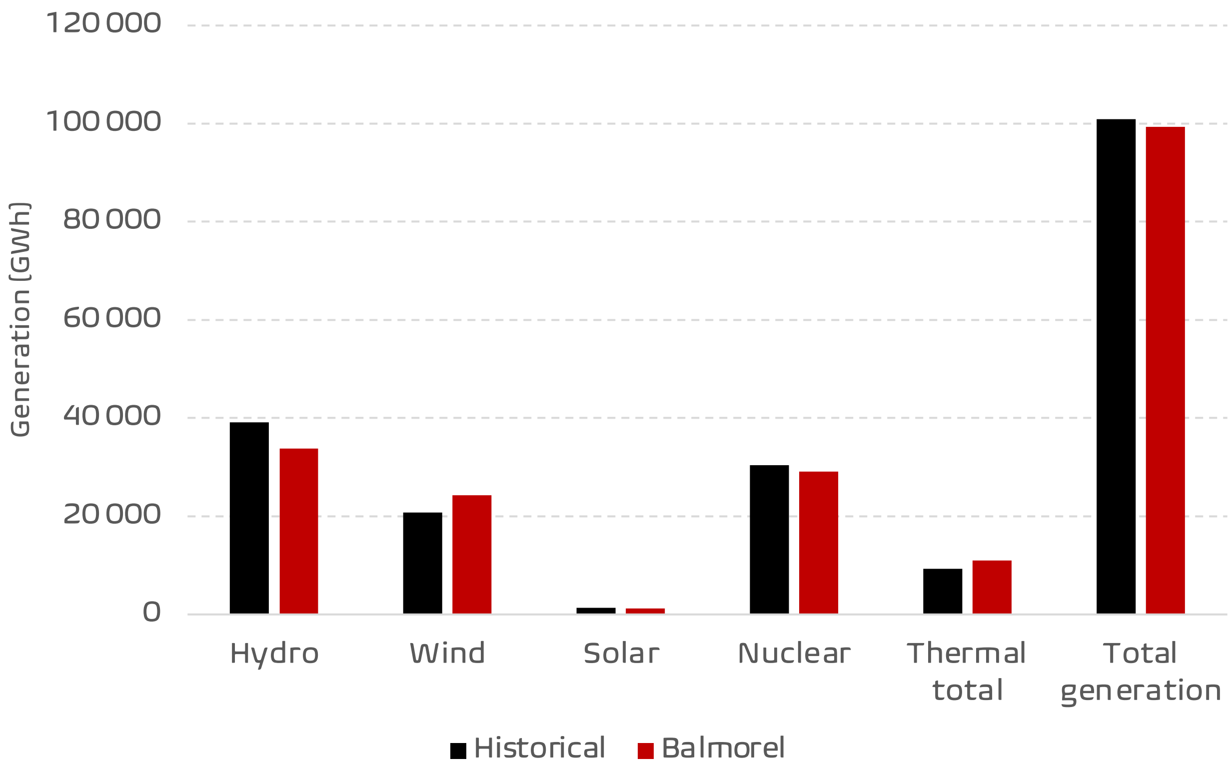
Model calibration
Electricity generation in Sweden

- The results from the model for the first 7 months of 2022 in terms of generation are very close to the realized ones
- Around 1% difference in the total generation amount
- Slightly less hydro (-14%) and Nuclear (-4%) and more wind (+16%) and thermal (+18%).



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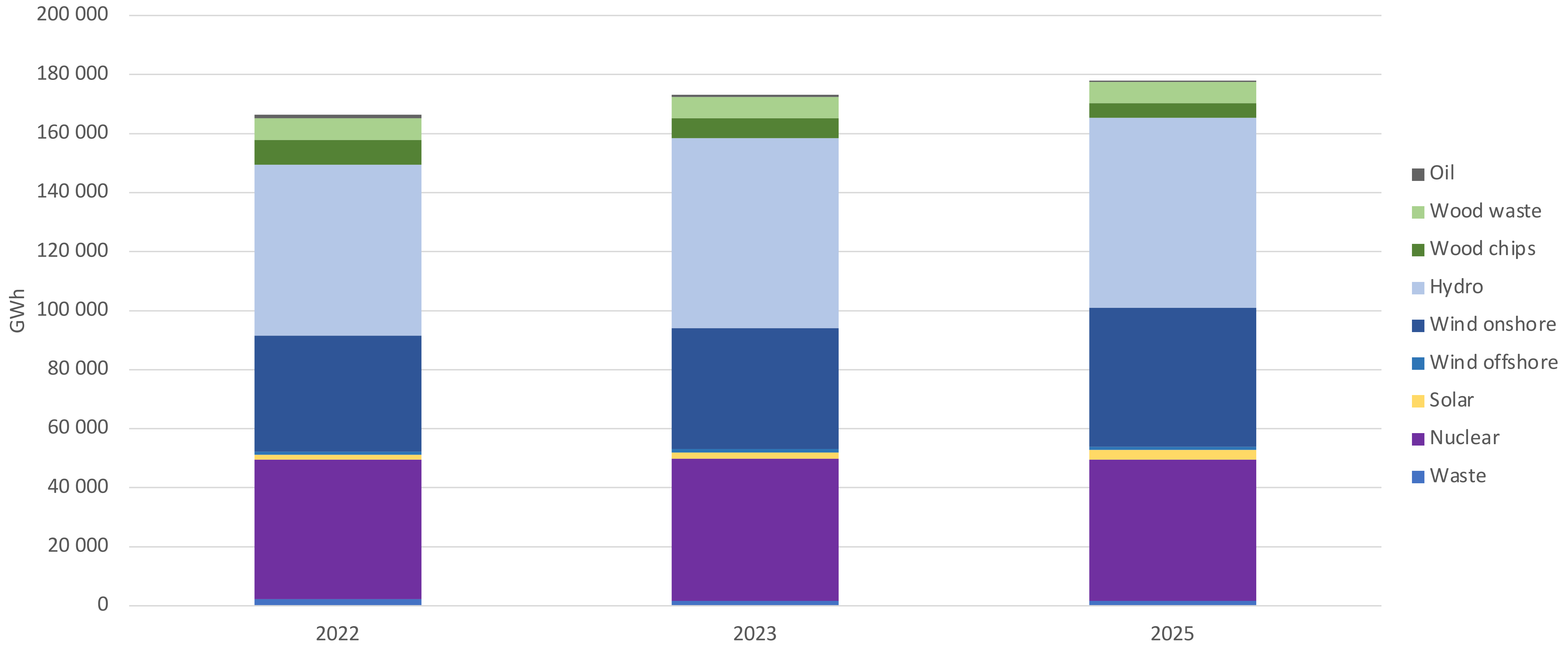
Electricity generation in Sweden in the Baseline scenario



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ANNEX C
Impact of tight gas supply on the Nordic electricity market

Lead organization: Profu AB

Analysts: Johan Holm and Thomas Unger

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Objectives

To analyse impact of current and assumed future gas prices on the Nordic electricity market and to assess to what extent current electricity prices may be dampened by a selection of measures.

Summary

- The price of electricity in southern Sweden (SE3 and 4) is doubled during the coming four months(sept-dec) compared to the previous 8 months.
- Reducing electricity consumption by means of efficiency measures or just reduction of load will have a significant impact on electricity prices
- Increased transmission capacity in Sweden will yield lower prices in the south but a lot higher prices in the north. Although not fully reaching ”one” bidding zone.
- Additional fossil fuelled generating capacity would help mitigate the highest electricity prices but increase emissions. But the dispatchability of this capacity is at this stage uncertain
- South of Sweden could, in the event of a total gas crisis, expect electricity prices which are virtually unlimited during 20 % of the period between sept-dec
- Looking into 2023 we see lower electricity prices even with a high and stagnated fossil fuel prices. The continuous rollout of renewable capacity is one factor that contributes to this and also one which we can influence

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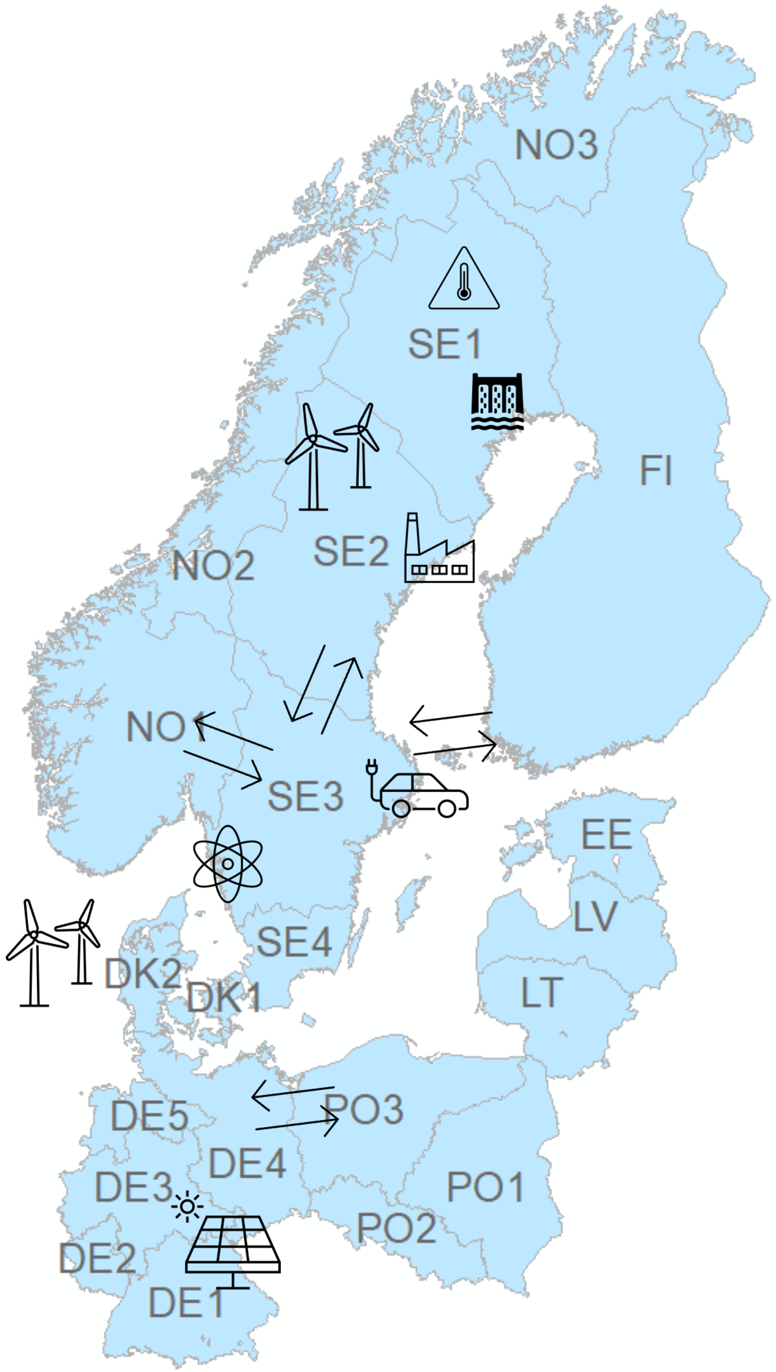
Our approach – The EPOD model

- European POwer Dispatch model - Dispatch model for Northern Europe (NEU).
- Simulates the generation of electricity in NEU and district heating in Sweden
- Key input data:
  - Consumtion of electricity and heat
  - Generators of electricity and heat
  - Representation of the transmission grid
  - Running costs of power plants
    - Fuel
    - O&M
    - Policy tools (EU ETS)
- The model minimizes system costs for producing electricity and heat
- Hourly balance of supply and demand yielding electricity prices for each ”price” region included in NEU



Our analysis

- The analysis is performed in two steps:
  - Creating reference cases
  - Testing (alternative) scenarios that can be compared to reference
- Two reference cases have been investigated, the year 2022 and the coming year of 2023
- Four additional scenarios were tested on 2022 and one on 2023.
- Reference 2022 and alternative scenarios:
  - Electricity demand reduction of 5 %
  - Nominal transmission capacity between SE2-3 and SE3-4
  - Additional fossil fuelled generating capacity in Sweden
  - Extreme high gas prices – indicating shortage
- Reference 2023 and alternative scenario
  - Electricity demand reduction of 5 %

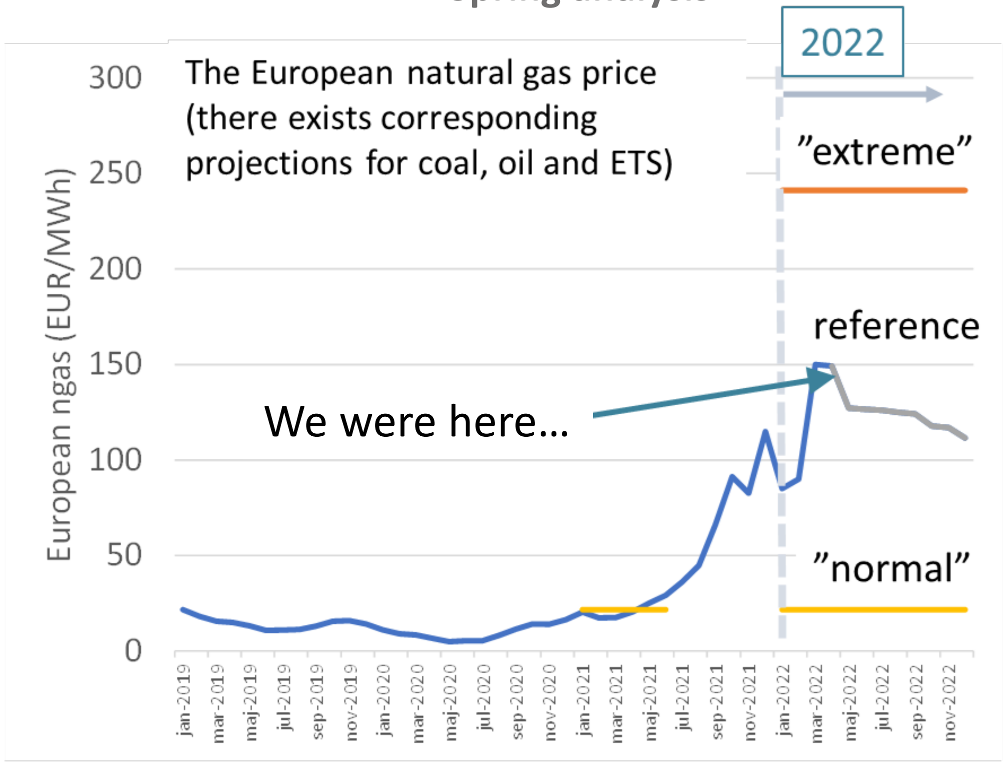
Our analysis (contd.)

- The year 2022 has been thoroughly investigated in order to create a reference case for 2022 that reflects actual conditions in 2022.
- The parameters that have been looked into and incorporated into the reference case for 2022 are the following:
  - Future energy prices for fossil fuels and EU ETS are taken from the futures market.
  - The hydro situation in NEU have been investigated and applied onto the hydro representation of the model. Basically Europe and Sweden and Norway is dryer than normal.
  - Electricity demand is kept at a normal level
  - The available transmission capacity is taken from the UMM on Nordpool and the actual availability for 2022 have been simulated
- Assumptions for the reference in 2023 is described on a later slide presenting the results from that simulation

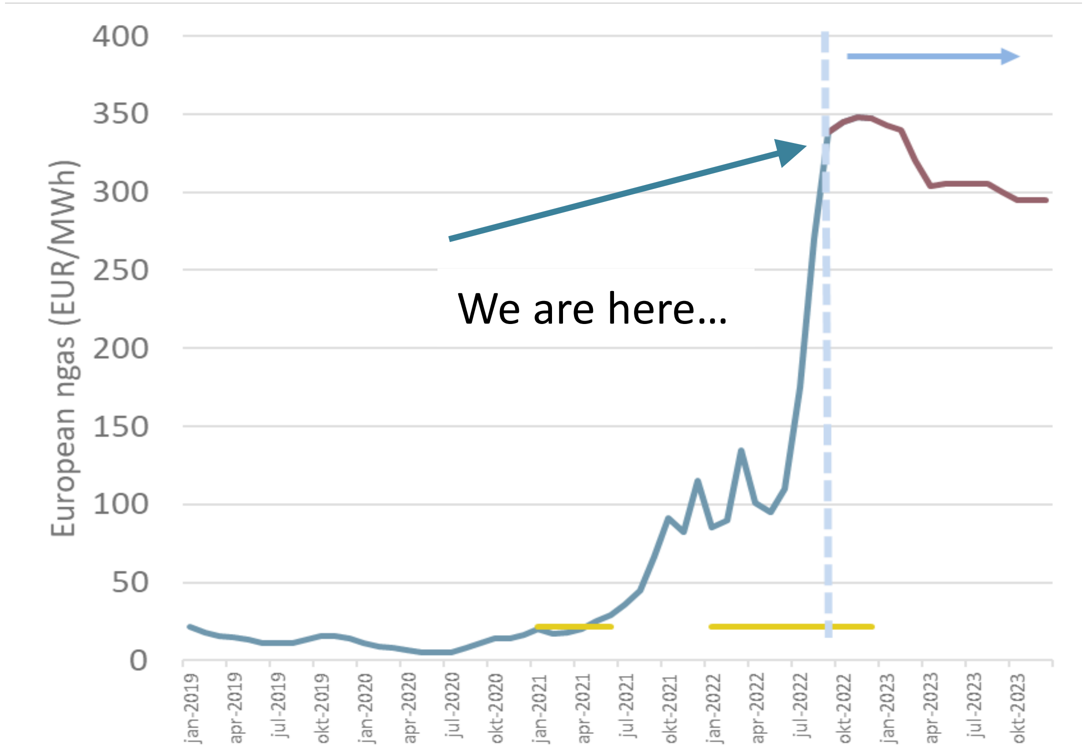
The futures market – a volatile place this year

This information is just to show the volatility of the market and the complex nature of trying to pick representativ energy prices for a near future simulation. The future prices that were used in the spring analysis showed a decline after mars but now we see that the price kept going steeply upwards. In the end we can conclude that the ”extreme” case in spring has significantly lower energyprices during som months than the actual outcome.

Spring analysis



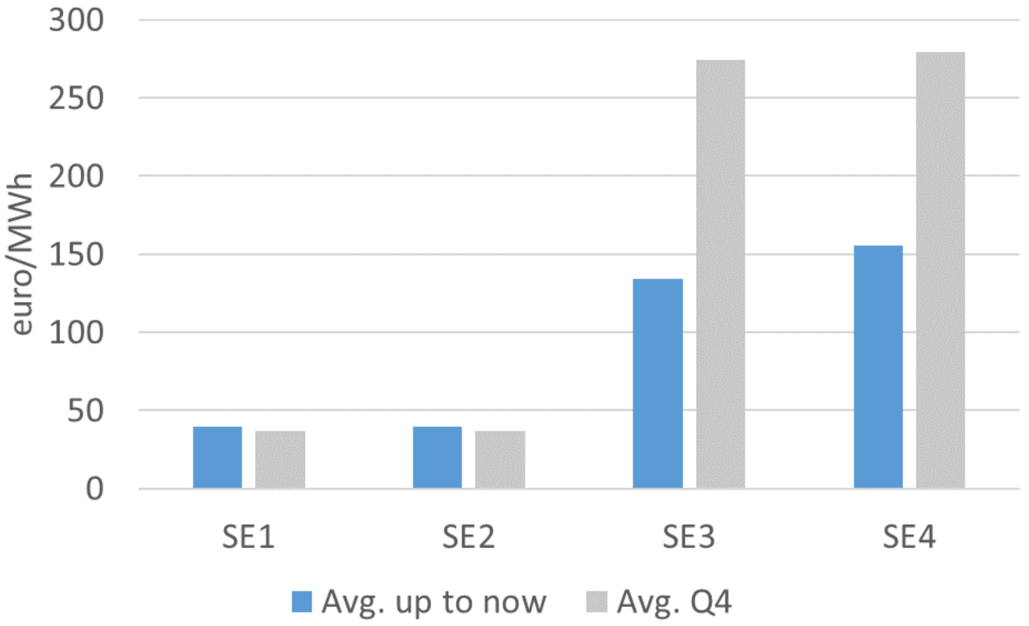
Autumn/winter analysis



The price of electricity in southern Sweden (SE3 and 4) is doubled during the coming four months(sept-dec) compared to price so far in 2022.

- Modeled average electricity price for the period Sep-Dec in SE3 ≈ 270 EUR/MWh,
- Large variations in electricity price is observed, 5 <-> 700 EUR/MWh
- Observed electricity price during September (so far) thus reflects the rest of the year's price level

- Leads to a doubling of the price of electricity in the coming months compared to the observed electricity price in 2022
- The modeled price situation is currently reflected in the futures market.



Major impact from reduced electricity consumption – short-term and future

- Energy efficiency measures or plain demand reduction that reduce the total electricity demand during Sep-Dec by 5% (throughout Northern Europe) reduce the price of electricity by ≈ 50 EUR/MWh, ≈ 18% for SE3 & 4
- The resulting cost reduction for consumers will be greater than 18% if the actual volume of electricity purchased has also decreased
- For the whole year 2023 (with different conditions and assumptions), the price of electricity will decrease by ≈ EUR 40/MWh (approx. 20%)

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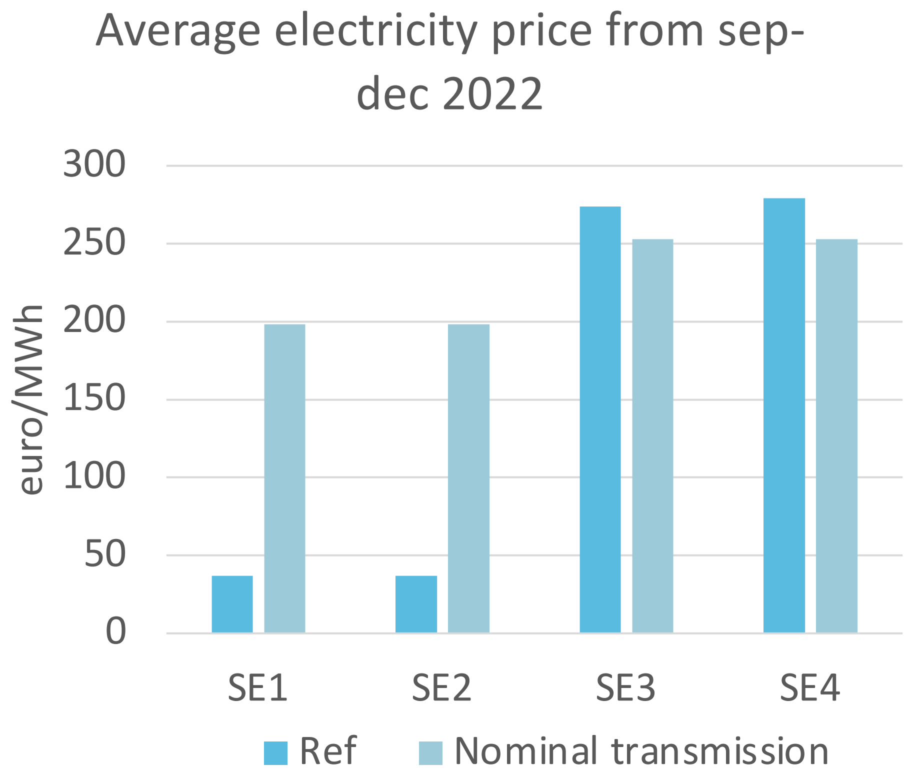
Increased electricity transmission capacity in Sweden yield lower electricity prices in the south and higher in the north

- Due to system stability reasons, Sweden has had to reduce access to transmission between electricity areas within Sweden but also to our neighboring countries. Reduced transmission:
  - SE2→SE3
    - Installed capacity: 7 300 MW,
    - Average modeled capacity in reference: 6 000 MW
  - SE3→SE4
    - Installed capacity: 6 200 MW
    - Average modeled capacity in reference: 4 400 MW
- Increasing electricity transmission capacity to nominal values results in a reduced electricity price in the south ≈ EUR 25/MWh and a significantly higher electricity price in the north > EUR 100/MWh (refers to the period Sept-Dec)



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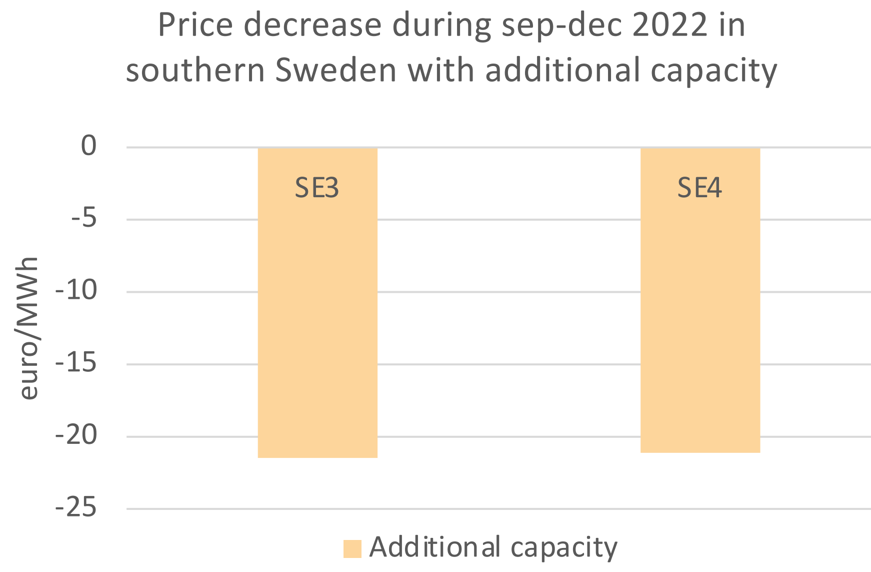
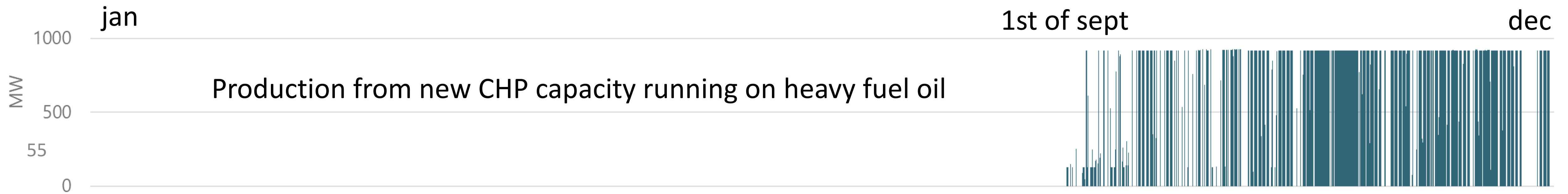
Potentially available (fossil) cogeneration can contribute and benefit the system (but with increased emissions)

- Large uncertainty about the real availability – but a capacity of around 1 GW has been communicated from industry
- These facilities are of varying status (reserve, mothballed, ..)
- Problems:
  - access to fuel (due to the status large quantities of fuel need to be obtained),
  - financing (some maintenance and other cost needs to be covered in order to make these plants operable) and
  - permits (legislative and environmental permits will in some form need to be issued or removed)
- Simulation with 1 GW of extra electricity capacity that run on heavy fuel oil indicates an electricity price reduction of ≈ 20 EUR/MWh (refers to the period Sept-Dec).
- These plants are expensive to run but with gas on the margin there is room for operating these plants





In the event of an extreme shortage of natural gas with huge price increases, southern Sweden may, at times, be subject to virtually “unlimited” electricity prices

- The model tests a scenario where the price of natural gas is extremely high (>1000 EUR/MWh) during September through December. The model then tries to solve the electricity balance in Northern Europe with all available plants that are not gas-fired.
- When the model can no longer avoid gas-fired plants, **very high prices** are obtained. The model simulation indicates that in SE4 for 20% of the time between September and December, these extremely high electricity prices are present (which in theory can become limitless). This, in turn, may imply significant voluntary or unvoluntary demand reductions.
- This also means that for 80% of the time, the price of electricity in SE4 is determined by something other than gas. Alternatively, SE4 is decoupled from the continental prices

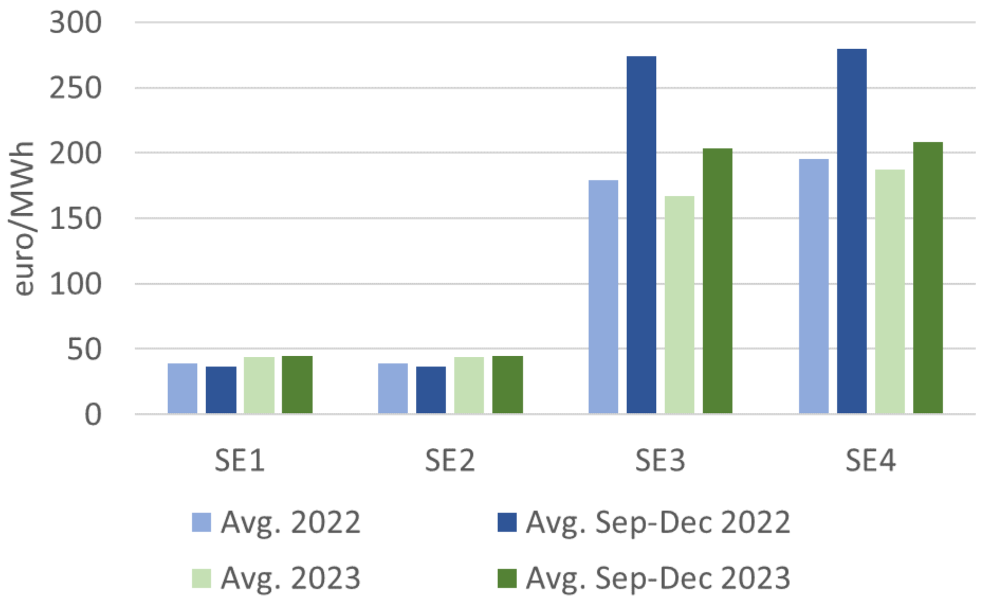
After a challenging winter, there are many indications that the situation in the electricity market in 2023 will ease (somewhat)

Assuming for 2023:

- More renewable in Northern Europe
- Normal operation of nuclear power in the Nordic region
- A normal hydropower year
- Stagnant high fossil prices indicated by the futures market
- Higher availability of transmission connections in the whole modeled region

The following results are obtained:

- The annual average price decreases by ≈ 10 EUR/MWh and the winter/autumn price decreases by ≈ 70 EUR/MWh compared to the same period in 2022
- With an energy efficiency improvement of 5% for the entire need in 2023, the annual average price and the winter/autumn price will decrease by ≈ 40 EUR/MWh compared to 2023



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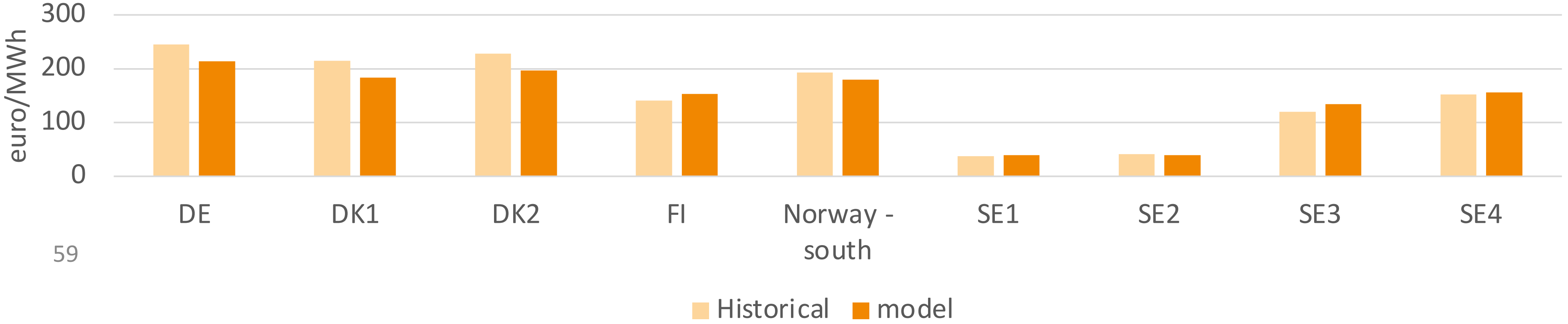
Benchmarking, limitations and uncertainties

- Running EPOD on a historical and present year with the aim of calculating electricity prices and how different measures affect the price, requires a lot of calibration.
- On the following slides we discuss the calibration method, limitations and uncertainties tied to our modeling.

Method of calibration

- EPOD has been calibrated with respect to the following:
    - Future energy prices for fossil fuels and EU ETS
    - The hydropower situation in NEU have been investigated and applied onto the hydro representation of the model. Basically Europe and Sweden and Norway is dryer than normal.
    - Electricity demand is monitored for the year and then kept at a normal level
    - The available transmission capacity is taken from the UMM on Nordpool and the actual availability for 2022 have been simulated
    - Actual export/import levels between regions have been surveyed and monitored in the model
- To assess the calibration quality we look into the electricity prices, production volumes from different energy sources and trade patterns.
    - For electricity prices we check the actual year so far and compare that with the model as well as comparing the comming months with what the futures market indicate. Having levels within close range and also the factor between observed prices and coming prices being close gives a good indication of the model behaving properly.
    - Another quality measure is comparing installed capacity and produced electricity from different energy sources in the model and in reality. We expect a certain amount of electricty coming from e.g. hard coal, if this value is much larger or lower we investigate and recalibrate if some assumption or parameter needs to be changed. This is an iterative process since one change influence the whole model solution and new possible deviations from reality can be found. The comparison is based on historical data as well as taking into account the actual market situation that we are in right now. We should for example expect more generation from coal/lignite during 2022 compared to previous years since gas is very expensive.
    - With trade patterns we mostly check that regions that are considered exporter or importers in reality also show this behavior in the modeling.
- Below is a graph showing the average price between 1st of jan and 11 of sept for the actual year (historical) and the model from the final calibration of 2022.



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Limitations of the study

- Of course there are limitations of what parameters we can calibrate and the electricity market is much more complex and depends on more factors(both within the power sector but also in other sectors that impact the power sector) that we can consider. One general example of this factors are risk, the model does not experience the element of risk that is constantly present for every actor in the power market. One reason for the models experiencing no risk is Perfect Foresight.
- The concept of Perfect foresight (PF) – when dealing with optimization models (in this case a linear programing model) you often run into an inherent advantage/disadvantage which is called perfect foresight. The mathematical structure of the modeling results in the model knowing everything everytime. This means that it is great at assessing the ***maximum potential*** of things that are dependent in time e.g. a energy storage which is utilized to its fullest potential because the model know, among other things, exactly how much the wind will blow for every hour over the simulation horizon (in this case one year). The drawback with this is that in our power system we have a lot of hydropower with reservoir that are used to shift electricity generation in time. The model then overestimates the potential in shifting water compared to reality.
- We are used to dealing with perfect foresight and deploy different measures to technologies that use storage so that the influence of PF can be decreased, but we can never reduce the influence to 0.

Further limitations regarding uncertatinties

- Weather
  - 2022 looks to be a dry year and has been modeled as that with respect to inflow and reservoir levels.
  - PV and wind generates according to a ”normal” year and actual wind patterns for 2022 have not been taken into account
  - Heating and electricity demand is also influenced by the weather but these parameters have also been modeled as ”normal”

Its important to note that the actual weather conditions the coming months can have significant impact on how we run the system. An autumn with poor wind generation will be much tougher on the rest of the system compared to a very windy one, where we could save more fuel and hydropower for the worst and most expensive hours.

- Access to reliable and complete data, when setting up the simulations we rely on reported data from many different sources. These are of varying quality and often we cross check data over several sources if possible. We then sometimes have to assume things about the reported data e.g. aggregated production data is distributed geographically. The quality of data and assumptions of course adds to the uncertainties. At Profu when deciding on assumption we tend to be quite conservative – if we don’t know we don’t want to exaggerate the impact of different measures or data.

- Using future prices on energy sources and timing of simulations. We have seen that the futures for especially natural gas has been very volatile and news on the market can make the price go drastically up as well as create a significant drop in price. The results in this modeling is therefor quite sensitive to when we picked the forward prices. It seems that we picked that at maybe their highest. Lower energy prices (but still very high) would influence the absolute levels of the electricity price but we would still expect to see the same dynamic behavior from our scenarios with respect to the reference case.

- No elasticity is modeled, not on demand and not on prices. For demand we assume a normal year and for prices we use the futures market. The impact of extremely high natural gas prices are investigated in one of the scenarios and can of course not fully substitute a dynamic elasticity behavior of the natural gas market but still gives great insights in what would be the affect of “ultra-extreme” high gas prices

LOWERING PRICES IN A HURRY

Russia's war on Ukraine followed by the energy war on Europe has led to a steep increase in energy prices. This report has analysed how different actions can lower electricity prices in Sweden.

Actions analysed include decreased electricity demand in different regions in Europe, increased electricity supply of wind, solar and thermal generation, and increased transmission capacity in Sweden.

The conclusion is that decreased demand is the fastest and most effective way to lower electricity prices in Sweden.

Energiforsk is the Swedish Energy Research Centre – an industrially owned body dedicated to meeting the common energy challenges faced by industries, authorities and society. Our vision is to be hub of Swedish energy research and our mission is to make the world of energy smarter!

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