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Gas demand in times of crisis: energy savings by consumer group in Germany

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Natural gas savings in Germany during the 2022 energy crisis

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Published online: 04 May 2023	Russia curbed its natural gas supply to Europe in 2021 and 2022, creating a
Published online: 04 May 2023 Check for updates	grave energy crisis. This Article empirically estimates the crisis response of natural gas consumers in Germany—for decades, the largest export market for Russian gas. Using a multiple regression model, we estimate the response of small consumers, industry and power stations separately, controlling for the nonlinear temperature-heating relationship, seasonality and trends. We find significant and substantial gas savings for all consumer groups, but with differences in timing and size. For instance, industry started reducing consumption as early as September 2021, while small consumers saved substantially only since March 2022. Across all sectors, gas consumption during the second half of 2022 was 23% below the temperature-adjusted
	baseline. We discuss the drivers behind these savings and draw conclusions on their role in coping with the crisis.

Europe is amid the most severe energy crisis since the oil price shock of 1973. Since mid-2021, spot prices of natural gas have been on a steep rise, reaching levels of ϵ 100–200 MWh⁻¹in 2022. This is about ten times the long-term pre-COVID-19 pandemic price levels of ϵ 15–20 MWh⁻¹. Specific events, such as Russia's invasion of Ukraine on 24 February 2022 and Russia's announcement of closing the North Stream 1 pipeline on 19 August 2022 (ref. 1), led prices to spike up to ϵ 227 and ϵ 339 MWh⁻¹, respectively. Meanwhile, the average gas price paid by German industry has increased sixfold when it peaked in September 2022, somewhat lagged and dampened by long-term contracts. Average German residential retail prices increased more than twofold between January and November 2022, before a political intervention substantially reduced households' energy bills in December 2022 (Fig. 1).

While the post-pandemic recovery has driven up energy prices around the world, the most important driver of European natural gas prices has been Russia's reduced supply. Even before Russia invaded Ukraine, Russia's Gazprom avoided filling its European gas storages during 2021 and stopped supplying the spot market in the fall of the same year. Starting in the winter, long-term contracts with individual countries and firms were no longer supplied either. By September 2022, imports from Russia to Germany via the North Stream 1 pipeline had ceased completely. With domestic European gas supply being limited, Europe turned to liquefied natural gas as a substitute, but global liquefied natural gas markets are tight, and European import terminal capacity is limited². As a result, reducing gas consumption has become key to European security of energy supply.

Previous non-academic surveys among German and European households find that every second to third respondent reported saving energy in response to the 2022 crisis3-5 (Supplementary Table 1 provides a summary). These surveys support the hypothesis of energy savings by households and provide insight into the motivation behind it. Notably, some respondents mentioned independence from Russian gas as the main driver of energy savings, in addition to increasing energy prices. However, in the context of studying environmentally motivated energy savings, the validity of self-reported measurements has often been questioned (ref. 6 provides a review). Also, the surveys cannot be used to estimate the magnitude of energy savings resulting from the indicated behavioural changes. Similarly, energy-intensive industries have been self-reporting production cuts since autumn 2021, but these insights cannot be translated into how much natural gas has been saved in the industry as a whole (collection of press releases in ref. 7).

Moreover, many existing analyses of the current energy crisis have reported reduced natural gas consumption based on comparing current with last year's consumption⁸⁻¹¹. Most importantly, these calculations do not control for temperature and hence cannot distinguish between savings in response to the crisis and the effect of stochastic weather variations. While more elaborate models have been used to

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Historic increase in natural gas prices



- TTF wholesale prices increased almost 10-fold, starting in Aug-Sep 2021
- Industry prices follow closely, while household prices start rising only in Jan 2022
- Wholesale and retail prices falling back to new normal in winter 2022



Reason(s) and solutions

Reason(s)

- Primarily Russia: not filling storages during 2021, not supplying wholesale markets since fall 2021, cutting long-term contracts starting in winter 2021/22, stopping to supply Nord Steam 1 end of Oct 2022
- To a lesser extent: post-pandemic recovery

Solutions

- Domestic European supply: long-term downward trend
- Liquified natural gas (LNG), but global markets are tight, import capacity is limited
- Reduced consumption

Question:

If and to what extent have firms and households responded to the energy crisis by reducing their consumption of natural gas so far?



Previous studies

Self-reported gas savings

- Industry reports production cuts since fall 2021 (Stiewe et al.)
- Households report behavioral change after the invasion of Ukraine (bitkom, tado, yougov)
- Often qualitative and incomplete

Analysis of aggregated consumption (Bruegel, BDEW, ICIS, BNetzA, ZEIT, DIW)

- Increasing evidence for reductions
- Often not, or only linearly, controlling for temperature (exceptions: ZEIT, DIW)
- Often not distinguishing between industry and the power sector

This study

- Aggregated consumption of small consumers, industry, and power sector
- Carefully controlling for the non-linear temperature-dependency of heating
- Controlling for (additional) seasonality, economic activity, power sector



Data



- Data on small (SLP) and large consumers (RLM) from Trading Hub Europe
 - "Small consumers": Households and small firms (annual consumption < 1.5 GWh)
 - "Large consumers": Industry, power sector, district heating (annual consumption > 1.5 GWh)
- Data on power sector gas consumption from DESTATIS
 - "Large consumers" consumption minus power sector gas consumption gives industrial (and district heating) gas consumption



Regression model(s)

One model for each consumer group

$$gas_t^s = a_0 + a_1 crisis_t + a_2 time_t + a_3 heat_t + e_t$$
(1)

$$gas_t^i = a_0 + a_1 crisis_t + a_2 time_t + a_3 heat_t + e_t$$
⁽²⁾

$$gas_t^p = a_0 + a_1 crisis_t + a_2 time_t + e_t$$
(3)

where

 $gas_t^s, gas_t^i, gas_t^p$ gas consumption of small, industrial, and power sector consumers $crisis_t$ vector of monthly crisis dummies $time_t$ vector of monthly time dummies as well as a linear time trend $heat_t$ simulated heating profile $a_0 \dots a_3$ model parameters (often vectors) e_t error term

Simulated heating profiles



From Ruhnau et al. (2019) / Ruhnau and Muessel (2022) ("When2Heat" dataset)

- Using sigmoid function of standard load profile method from BDEW, accounting for the non-linear dependency between ambient temperature and heating
- Applied to spatial temperature data from the ERA5 reanalysis weather model



Pre-crisis residuals << estimated savings



Estimated gas savings



Small consumers substantially reduce consumption since Mar 2022

- Matching lagged price increase
- Maybe also due to public attention
- Seasonal: larger in heating period but not too much variation within

Industry substantially reduces consumption since Sep 2021

- Increasing with prices/over time
- Without economic collapse

Power sector depends on other sources

Nuclear, hydro, other renewables



Temperature matters, robust results otherwise



Savings relative to estimated baseline



Small consumers' savings are less seasonal than baseline

- Relative savings largest in September (28%)
- Smaller relative numbers in summer (nothing to save) and winter (harder to save)

Industry savings' increase over time dominates seasonality

- Largest absolute and relative savings coincide (30% in Dec '22)
- Without economic collapse

Power sector depends on other sources

Nuclear, hydro, other renewables



Why was consumption reduced?



- No prices in our model due to reverse causality and measurement error
- However: strong negative correlation between prices and demand
- Implied household elasticity of -0.34 and industry elasticity of -0.03 (pass-through)
- Other drivers: salience (incl. campaigns), ethical motives (for households), economic activity... → Further research



How was consumption reduced and will it come back?



Plant relocation (BASF) Heat pumps Wind & solar energy Hydraulic balancing & lower flow temperatures More efficient ventilation Coal plants back on grid Lower room temperatures Import substitution short-term long-term

Lead time

14

Color coding:

Industry

Power sector

Small consumers

Conclusions

Direct conclusions

- Significant natural gas savings during the energy crisis in Germany
- Average over second half of 2022 across sectors is 23% below estimated baseline
 → much more than we would have expected (what about you?)
- Our results suggest market prices effectively coordinate and incentivize savings (important for relief package design), but there may also be other drivers

Outlook

- More research on the "why" and "how" of gas savings in and beyond the crisis
- Less reason for state-supported LNG terminals
- Indicative evidence on behavioral changes and incentives related to climate policy



Thank you!



Link to the article

Side note: price indexes differ and hide heterogeneity



- Our understanding:
 - Both are averages of old and new contracts
 - Unclear what causes the difference
- Individual differences must be much larger \rightarrow incentive problem



Overview of pre-crisis natural gas flows in DE

Erdgasfluss 2021 (vorläufig) in Mrd. kWh



Quellen: Destatis, BVEG, Entsog, BDEW, dena; Stand 04/2022 Rundungsdifferenzen 2021 wurden zudem 10,1 Mrd. kWh auf Erdgasqualität aufbereitetes **Biogas** in das deutsche Erdgasnetz eingespeist.

BDEW 2022

Industry response according to press releases



Sources: press releases companies and associations. news articles. 1: Yara reduces ammonia production in Europe by 40% due to high gas prices and imports ammonia instead. keeping the downstream fertilizer production running as usual; 2: BASF reduces ammonia production in DE and BE due to 3: SKW high gas prices; Priesteritz reduces ammonia production in DE by 20% due to high gas prices; 4: Trimet reduces aluminum production by Yara re-increases 30%: 5: ammonia production in Europe; 6: Yara reduces ammonia production in Europe; 7: Norske Skog stops paper production due to high gas prices; 8: Several members of the German brick industry association reduce their production due to high gas prices in DE: 9: Stahlwerke Lech stops steel production due to high electricity prices on a daily basis in DE; 10: Salzgitter reduces steel production due to high electricity prices on a shift-wise basis; 11: Trimet reduces aluminum production by 50% in Essen (DE); 12: Norske Skog reincreases paper production.

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Demand is responding

Remaining question: By how much?

Stiewe et al. 2022



Ammonia production and imports



Sources: production and trade data from German Federal Statistical Office; **Notes:** NWE is the north-western European price for cost and freight (CFR); TTF is the Title Transfer Facility price in the Netherlands; the axis of the natural gas price is scaled by a factor of nine because 9 MWh of natural gas are used to produce 1t ammonia (based on IEA).

Ammonia industry saved 1.6 TWh in 2nd half of 2021

• Remaining question: How large were economy-wide savings?

Stiewe et al. 2022

No economic collapse



Umsatz in Branchen des Verarbeitenden Gewerbes

- Not all reductions were due to energy
- Also: supply chain problems due to Ukraine war and China lockdown



Dashboard