Full Russian gas embargo: fallback scenarios that secure European industry by reduced heating

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Note: Working draft, version 0.10 of 19 June 2022 (Data, most recent as well as older versions at: https://github.com/hblasum/stop-gas-imports). *This is currently a work of "citizen science", driven by a need to understand the topic independently. We are very interested in review / feedback from any (also academic, professional) parties.*

Abstract: Concerns have been raised that a gas embargo would hurt European industry and that the potential for industry-save savings is low without harming supply chains. Here we calculate scenarios with low industry savings, based on current Eurostat energy data available for 2019/2020, with a focus on 2019 (i.e. pre-COVID-19) data.

If in a baseline scenario, we take as economic entity the EU, and assume that gas for public electricity generation with CHP (combined heat and power) is reduced by 20%, gas for public electricity generation for non-CHP is 80% substituted, gas use for industry is saved by 12%, Russian imports are substituted by 35%, then the needed savings needed from consumers (households / public / non-industry commercial) are 34%. If we take as economic entity the EU plus Iceland, Liechtenstein, Norway, United Kingdom, Montenegro, North Macedonia, Albania, Bosnia and Herzegovina, Kosovo, Moldova and Ukraine, then the needed savings from consumers are only 14%.

Policy implications for the EU are to seek solidarity with non-EU gas embargo friendly countries, primarily UK, to halt any prioritization of consumers, and to prepare consumers to save on heating. For social acceptance, even if results are expected to be less than on the consumer side, industry at least should show also sincere efforts to review energy usage.

We also provide a spreadsheet that allows you to vary the assumptions and calculate alternative scenarios.

1 Introduction and objective

As of 18 June 2022, the cruel war in Ukraine is being financed by Europe to the extent of more than 62 billion EUR since 24 February.[1] As an excuse, it has been frequently argued that European industry depends on gas so much that an embargo cannot be done. We argue that an embargo is possible without almost touching industry consumption, largely by cutting private consumptions. We also give a hypothetical scenario of full embargo without any new imports and sourcing and with almost no contribution for industry, and then the cut in private consumption is very large. The objective of the write-up is not to state that such a radical industry protection is

[1] https://beyond-coal.eu/russian-fossil-fuel-tracker/

the only way to go ahead, as presumably larger savings are also possible in the industry, but to give assurance that even if it would turn out that realizable industry savings and substitution options were in fact minuscule, then a gas embargo still would not lead to any industrial breakdown.

Ethically and strategically there are strong arguments why there is an obligation for Europe to stop gas imports and why they have impact.[2] This holds regardless whether one is in favor or against additional delivery of weapons or not: for supporters of weapons deliveries, the embargo is an additional means that should be taken; for those who object weapons deliveries, the embargo potentially is one of the very few effective means that can be taken. Even if you disagree, e.g. arguing that e.g. the export embargo alone is successful enough and do not wish an embargo at all, or you favor tarriffs over embargo, our observations might be equally useful to understand the situation when Russia would could the gas exports on its side.

Numerous economic studies have already argued that, based on price elasticity, a gas embargo can be done with only moderate costs for instance to the German economy at a cost of less than 3% GDP,[3] comparable to the financial crisis or COVID-19 economical shrinking. However, the German government seems to refuse to accept arguments based on price elasticity, worrying that in worst-case scenarios that (1) price elasticity values derived from normal situations do not carry over to a deep economic transformation and (2) core industries that are at the bottom of the value chain are especially endangered, such as for instance the chemical industry that has been relatively strong in Germany since the 19th century.

A BDEW working paper claims only 8% savings in industry to be feasible.[4] In the following, in a conservative scenario with only slightly stronger efforts, we assume 12%. For the public electricity grid, there is enough capacity for power generation from coal and overall for electricity generation gas only plays a minor role, e.g. 12.6% in Germany in 2021,[5] however some of the gas electricity plants are used for CHP (combined heat and power generation), moreover for peak balancing gas-powered plant might be slightly more flexible than coal-based plants. We assume that the

[2] L Rachel. "RUSSIA ENERGY BAN MYTH BUSTER: Frequent Arguments against Taking Action Now, and Why They Don't Stack up," https://t.co/L26ZGfX9IK

[3] E.g. Bachmann, R., Baqaee, D., Bayer, C., Kuhn, M., Löschel, A., Moll, B., Peichl, A., Pittel, K., & Schularick, M. 2022. Was wäre, wenn...? Die wirtschaftlichen Auswirkungen eines Importstopps russischer Energie auf Deutschland. https://www.econtribute.de/RePEc/ajk/ajkpbs/ECONtribute_PB_029_2022.pdf; Leopoldina. (2022). Wie sich russisches Erdgas in der deutschen und europäischen Energieversorgung ersetzen lässt. https://www.leopoldina.org/fileadmin/redaktion/Publikationen/Nationale_Empfehlungen/2022_Stellungnahme_Energiesicherheit.pdf; Zimmer, Markus, Katharina Utermöhl, and Ano Kuhanthan, Allianz Research, "CAN EUROPE DO WITHOUT RUSSIAN GAS?," 2022. https://www.allianz.com/content/dam/onemarketing/azcom/Allianz_com/economic-research/publications/specials/en/2022/march/2022_03_03_EU_without_russian_gas.pdf

[4] BDEW. "Fakten Und Argumente Kurzfristige Substitutions- Und Einsparpotenziale Erdgas in Deutschland," March 17, 2022. BDEW. "Kurzfristige Substitutions- und Einsparpotenziale Erdgas in Deutschland," n.d., 22. https://www.bdew.de/media/documents/Kuzfristige_Gassubstitution_Deutschland__final_17.03.2022_korr1.pdf; also BDEW. "Monatlicher Erdgasverbrauch in Deutschland 2021 - Vorjahresvergleich." https://www.bdew.de/service/daten-und-grafiken/monatlicher-erdgasverbrauch-deutschland/ page 3

[5] Statistisches Bundesamt. "Stromerzeugung 2021: Anteil konventioneller Energieträger deutlich gestiegen." Accessed April 15, 2022. https://www.destatis.de/DE/Presse/Pressemitteilungen/2022/03/PD22_116_43312.html.

public electricity plants without CHP can be 80% substituted and public electricity plants with CHP can be substituted 20% The aforementioned BDEW working paper projected 54% gas savings potential for public electricity generation, which seems roughly compatible.[6]

In the following we show that it is possible to stop immediately Russian gas with when there is a strong contribution from consumer savings: That is, if we take as economic entity the EU, and assume that gas for public electricity generation with CHP (combined heat and power) is reduced by 20%, gas for public electricity generation for non-CHP is 80% substituted, gas use for industry is saved by 12%, Russian imports are substituted by 35%, then the needed savings needed from consumers (households / public / non-industry commercial) are 34%. If we take as economic entity the EU plus Iceland, Liechtenstein, Norway, United Kingdom, Montenegro, North Macedonia, Albania, Bosnia and Herzegovina, Kosovo, Moldova and Ukraine, then the needed savings from consumers are only 14%. Unlike many price elasticity models, mathematically our approach is very simple: it is just an addition of Eurostat publicly available numbers. We show both a European as well as a German view.

2 Methodology (high-level)

The research questions is: how much consumer energy savings are needed under certain given savings / conversions in electricity generation and industry use.

Our methodology is very simple, we calculate from certain savings in industry, import substitution and power generation conversion from gas (to e.g. coal) the needed consumer savings, with consumers being households / public sector / commercial (non-industry) sector.

We are using public Eurostat data and does additions on the appropriate categories (e.g. power generation at industry plants is conservatively fully subsumed under industry, details on this subsumption given in Section 6). At Eurostat, the 2021 data is not yet available and the most recent year is 2020 data. However, to be on the safe side, 2019 has been intentionally selected as the year with the highest imports Europe and the EU had made from Russia ever: gas imports to the EU have been growing since the statistics are available (since 1990) and peaked in 2019, as 2020 imports were slightly lower, due to COVID-19. An additional advantage of selecting 2019 data over 2020 data is that the 2019 data is probably more finalized than then 2020 data.

All data / assumptions are public available at https://github.com/hblasum/stop-gas-imports .

3 Embargo with reduced gas import balanced by consumers

3.1 Scenario with substitution from import diversification, renewable substitution and consumer savings

Table 1 shows Russian imports into Europe, Table 2 shows substitution of these imports and Table 3 shows, as source of potential energy savings, current consumption for the countries that are likely to support the energy embargo against Russia (EU plus Iceland, Liechtenstein, Norway,

[6] BDEW, cited previously, page 3.

United Kingdom, Montenegro, North Macedonia, Albania, Bosnia and Herzegovina, Kosovo, Moldova and Ukraine), **henceforth for brevity called "Europe".**

Table 1: Russian gas imports into Europe and EU in PJ (petajoule = 10^{15} Joule).

	Eurostat 2019[7]	Eurostat 2020
Gas imports from Russia to Europe	7094 PJ	6500 PJ
Gas imports from Russia to EU	7038 PJ	6443 PJ

As shown in Table 2, the EU has calculated 3247 PJ for realizable short-term (2022) substitution by imports or switching to renewables[8], which amounts to a substitution of 35.0% of Russian imports if only include direct substitution of gas, or even 45.8% of the Russian imports if we include additional renewable generation.

Table 2: Short-term gas substitution from imports and energy substitution

Item	Bcm	PJ (at 38.2 PJ / bcm[9])
LNG replacements	50	1910 PJ
Pipeline import diversification (e.g. Algeria[10])	10	382 PJ
Additional biomethane production	4	134 PJ
Heat pump rollout	2	57 PJ
SUM targeting direct gas import/consumption substitution	65	2483 PJ
Wind and solar front loading[11]	20	764 PJ
SUM overall	85	3247 PJ

Table 3 summarizes gas consumption in Europe. Our main actors are households, commercial and public services (we summarize households, commercial and public services as "consumers"),

[7] Eurostat. "Custom Dataset: Imports of Natural Gas by Partner Country." Accessed April 4, 2022. https://ec.europa.eu/eurostat/databrowser/view/NRG_TI_GAS__custom_2428849/default/table?lang=en. This custom dataset is based on Eurostat. "Imports of Natural Gas by Partner Country - Products Datasets - Eurostat." Accessed April 4, 2022. https://ec.europa.eu/eurostat/web/products-datasets/-/nrg_ti_gas

[8] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS REPowerEU: Joint European Action for more affordable, secure and sustainable energy (2022). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A108%3AFIN

[9] International Energy Agency, ed. World Energy Outlook 2011. World Energy Outlook 2011. Paris, 2011. https://iea.blob.core.windows.net/assets/cc401107-a401-40cb-b6ce-c9832bb88d85/WorldEnergyOutlook2011.pdf. page 304

[10] Reuters. "Italy Clinches Gas Deal with Algeria to Temper Russian Reliance." Reuters, April 11, 2022, sec. Energy. https://www.reuters.com/business/energy/italy-signs-deal-with-algeria-increase-gas-imports-2022-04-11/.

[11] Numbers consistent with Zimmer, Markus, Katharina Utermöhl, and Ano Kuhanthan. "CAN EUROPE DO WITHOUT RUSSIAN GAS?," 2022. https://www.allianz.com/content/dam/onemarketing/azcom/Allianz_com/economic-research/publications/specials/en/2022/march/2022_03_03_EU_without_russian_gas.pdf where 1000 PJ are given as possible substitution.

electricity generation for the public grid, which we split up into CHP (combined power and heat) and non-CHP (i.e. electricity-only generation) and industry, including non-energy use (e.g. for chemical processes). Also on-site electricity autogeneration has been fully assigned to industry.

Table 3: Gas consumption in Europe (derivation see Section 8)

Area	Item	Primary energy consumption Eurostat 2019[12]	%	Primary energy consumption Eurostat 2020	%
Europe (EU plus Iceland, Liechtenstein, Norway, United Kingdom, Montenegro, North Macedonia, Albania, Bosnia and Herzegovina, Kosovo, Moldova and Ukraine)	Households	5627 PJ	28%	5578 PJ	28%
	Commercial and public services	2032 PJ	10%	1955 PJ	10%
	Electricity generation (public grid/no CHP)	2853 PJ	14%	2812 PJ	14%
	Electricity generation (public grid/CHP)	1769 PJ	9%	1738 PJ	9%
	Industry	7515 PJ	37%	7342 PJ	37%
	Transport	93 PJ	0%	90 PJ	0%
	Other	160 PJ	1%	150 PJ	1%
	SUM	20949 PJ	100%	19665 PJ	100%
EU	Households	3959 PJ	26%	3913 PJ	26%
	Commercial and public services	1681 PJ	10%	1605 PJ	11%
	Electricity generation (no CHP, public grid)	2006 PJ	13%	1960 PJ	13%
	Electricity generation (CHP, public grid)	1634 PJ	11%	1571 PJ	10%
	Industry	6050 PJ	39%	5894 PJ	39%
	Transport	86 PJ	1%	84 PJ	1%
	Other	72 PJ	0%	61 PJ	0%
	SUM	15488 PJ	100%	15088 PJ	100%

Table 4 shows a baseline scenario where we take as economic entity the EU, and assume that gas for public electricity generation with CHP (combined heat and power) is reduced by 20%, gas for public electricity generation for non-CHP is 80% substituted, gas use for industry is saved by 12%, Russian imports are substituted by 35%, then the needed savings needed from consumers (households / public / non-industry commercial) are 34%. If we take as economic entity the EU plus Iceland, Liechtenstein, Norway, United Kingdom, Montenegro, North Macedonia, Albania, Bosnia and Herzegovina, Kosovo, Moldova and Ukraine, then the needed savings from consumers are only 14%.. “Old” is the 2019 baseline scenario, “savings” are the savings with the above-

[12] “Eurostat: Custom Dataset: Supply, Transformation and Consumption of Gas.” Accessed March 30, 2022. https://ec.europa.eu/eurostat/databrowser/view/NRG_CB_GAS__custom_2395063/default/table?lang=en .This custom table is based on Eurostat. Statistics “Supply, Transformation and Consumption of Gas.” Accessed March 30, 2022. https://ec.europa.eu/eurostat/databrowser/view/NRG_CB_GAS/default/table?lang=en&category=nrg.nrg_quant.nrg_quanta.nrg_cb .

mentioned savings implemented. The balance is substitution minus Russian gas imports, where this balance is positive, the country / geographic unit can cut Russian gas without European imports; where this balance is negative, the country needs other (non-Russian) European imports (taken from the positive balance of other countries: e.g. the surplus of 110 PJ of Belgium can be fed into the deficit of 42 PJ of Bulgaria). The table shows that under this strong savings scenario the inter-country gas flows are relatively small and thus should be manageable by the European gas network. From the embargo-friendly non-EU European allies, the lion's share in contribution is UK (positive contribution 1254 PJ) and Ukraine (positive contribution 268 PJ), whereas the other non-EU allies' contributions/ needs overall are rather minor.

Table 4: Scenario where gas for public electricity generation with CHP (combined heat and power) is reduced by 20%, gas for public electricity generation for non-CHP is 80% substituted, gas use for industry is saved by 12%, Russian imports are substituted by 35%. All table value entries are in PJ.

Country	Gas imports Russia old	Import substitution	Household old	Household savings	Commercial / public old	Commercial / public savings	Electricity no CHP old	Electricity no CHP savings	Electricity CHP old	Electricity CHP savings	Industry old	Industry savings	Substitution	Balance
Belgium	150	53	151	51	88	30	98	78	50	10	318	38	260	110
Bulgaria	91	32	11	4	4	1	0	0	29	6	52	6	49	-42
Czechia	364	128	103	35	55	19	26	21	22	4	119	14	221	-144
Denmark	0	0	40	14	9	3	0	0	19	4	57	7	28	28
Germany	1803	631	1118	380	440	150	202	162	389	78	1365	164	1564	-239
Estonia	19	7	8	3	3	1	0	0	0	0	6	1	11	-8
Ireland	0	0	27	9	19	6	105	84	0	0	57	7	107	107
Greece	65	23	18	6	7	2	127	102	0	0	54	6	139	74
Spain	256	90	161	55	91	31	417	334	0	0	750	90	599	343
France	707	247	558	190	278	95	161	129	87	17	636	76	754	48
Croatia	0	0	23	8	10	3	0	0	24	5	50	6	22	22
Italy	1274	446	762	259	330	112	429	343	543	109	712	85	1355	80
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latvia	51	18	13	4	5	2	0	0	26	5	6	1	30	-21
Lithuania	46	16	11	4	3	1	0	0	6	1	67	8	30	-16
Luxembourg	9	3	12	4	5	2	0	0	2	0	13	2	11	2
Hungary	689	241	152	52	49	17	32	26	41	8	112	13	357	-332
Malta	0	0	0	0	0	0	14	11	0	0	0	0	11	11
Netherlands	733	256	318	108	130	44	255	204	163	33	618	74	720	-13
Austria	0	0	75	25	17	6	35	28	50	10	179	22	91	91
Poland	371	130	177	60	63	21	0	0	62	12	413	50	273	-97
Portugal	8	3	13	4	11	4	87	70	0	0	122	15	96	88
Romania	37	13	129	44	38	13	1	1	63	13	179	21	105	68
Slovenia	4	1	6	2	1	0	0	0	4	1	22	3	8	4
Slovakia	260	91	59	20	19	6	12	10	16	3	73	9	139	-121
Finland	101	35	11	4	1	0	1	1	31	6	37	4	51	-50
Sweden	0	0	1	0	5	2	0	0	5	1	34	4	7	7
SUM EU	7038	2463	3959	1346	1681	572	2006	1605	1634	327	6050	726	4575	0
Iceland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liechtenstein	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Norway	0	0	1	0	2	1	0	0	0	0	258	31	32	32
United Kingdom	0	0	1116	379	305	104	836	669	0	0	851	102	1254	1254
Montenegro	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Macedonia	11	4	1	0	0	0	0	0	8	2	2	0	6	-5
Albania	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Bosnia and Herzegovina	9	3	4	1	1	0	0	0	0	0	4	0	5	-4
Kosovo	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moldova	35	12	14	5	4	1	0	0	10	2	5	1	21	-14
Ukraine	0	0	533	181	38	13	11	9	117	23	342	41	268	268
SUM Europe	7094	2483	5627	1913	2032	691	2853	2283	1769	354	7515	902	6142	1531

3.2 Calculation of alternative scenarios

For a scenario calculation, if we set *imports* (7094 PJ for Europe 7038 PJ for the EU as per Table 1) to be the current imports of Russian gas, *imports_substitution_rate* to be the substitution rate of these gas imports by alternatives (as in Table 2), *electricity_no_chp* (2853 PJ for Europe, 2006 PJ for the EU as per Table 3) to be amount of gas used for electricity generation without CHP, *electricity nochp_substitution_rate* the rate for substitution of electricity generation without CHP, *electricity_chp* (1769 PJ for Europe, 1634 PJ for the EU as per Table 3) to be amount of gas used for electricity generation with CHP, *electricity chp_substitution_rate*, for the rate for substitution of electricity generation with CHP, *industry* the consumption of gas by industry (7515 PJ for Europe, 6050 PJ for the EU), *industry_savings_rate* to be the savings rate in industry, *household* to be the amount of household consumption (5627 PJ for Europe, 3959 PJ for the EU) and *commercial* the amount of commercial and public consumption (2032 PJ for Europe, 1681 PJ for the EU), then the formula to calculate the required household and commercial / public savings is:

*Required_household_savings = (imports - (imports * imports_substitution_rate + electricity_nochp * electricity_nochp_substitution_rate + electricity_chp * electricity_chp_substitution_rate + industry * industry_savings_rate)) / (household + commercial)*

Table 5 below applies this formula to calculate different scenarios. (Also as spreadsheet at https://github.com/hblasum/stop-gas-imports/blob/master/data/consumer-savings-calculation.xlsx).

Table 5: All scenarios, including fallback and alternative scenarios

Line number	Scenario	Section in this document	EU/Europe	Import substitution rate	Electricity (no CHP) substitution rate	Electricity (CHP) substitution rate	Industry savings rate	Substitution amount needed (PJ)	Substitution amount by previous (PJ)	Still needed savings (PJ)	Savings rate
1	Baseline	3.1	EU	35.0%	80.0%	20.0%	12.0%	5121	1917	2643	34.0%
2		3.1	Europe	35.0%	80.0%	20.0%	12.0%	6021	1073	1799	14.0%
3	Weak industry savings	3.2.1	EU	35.0%	80.0%	20.0%	8.0%	4879	2159	2643	38.3%
4		3.2.1	Europe	35.0%	80.0%	20.0%	8.0%	5720	1374	1858	17.9%
5	Strong import substitution	3.2.1	EU	45.0%	80.0%	20.0%	12.0%	5825	1213	1939	21.5%
6		3.2.1	Europe	45.0%	80.0%	20.0%	12.0%	6730	364	1090	4.7%
7	CHP substitution 0	3.2.1	EU	35.0%	80.0%	0.0%	12.0%	4794	2244	2970	39.8%
8		3.2.1	Europe	35.0%	80.0%	0.0%	12.0%	5667	1427	2153	18.6%
9	Zero import substitution	3.2.2	EU	0.0%	80.0%	20.0%	12.0%	2658	4380	5106	77.7%
10		3.2.2	Europe	0.0%	80.0%	20.0%	12.0%	3538	3556	4282	46.4%
11		3.2.2	EU	0.0%	50.0%	0.0%	8.0%	1487	5551	6035	98.4%
12		3.2.2	Europe	0.0%	50.0%	0.0%	8.0%	2028	5066	5550	66.1%
13		3.2.2	EU	0.0%	0.0%	0.0%	0.0%	0	7038	7038	124.8%
14		3.2.2	Europe	0.0%	0.0%	0.0%	0.0%	0	7094	7094	92.6%

3.2.1 Some variations with substitutions

Weak industry savings: Table 5 lines 3 and 4 give a more conservative scenarios with lower industry savings of only 8% of electricity generation substitution as per BDEW (see Section 1). This only would entail slightly higher needed energy savings from European consumers (2643PJ/1858 PJ).

Strong import substitution: As another alternative (Table 5 lines 5 and 6) we have calculated a scenario with 45% import substitution. Whether such a high import substitution can be realized remains to be seen.

CHP substitution 0: Table 5 lines number 7 and 8 show scenarios with an electricity generation substitution of 0% instead of 20% in CHP.

3.2.2 No substitution at all scenario

Table 1 and Table 3 show that for Europe 2019 numbers (EU plus Iceland, Liechtenstein, Norway, United Kingdom, Montenegro, North Macedonia, Albania, Bosnia and Herzegovina, Kosovo, Moldova and Ukraine) the consumption by households + public and commercial of 5627 PJ + 2032 PJ = 7659 PJ alone, which is largely used for heating, is larger than Russian gas imports of 7038 PJ. That is, a gas embargo borne by households/public/commercial users (savings of 92.6%) could be done with neither touching industry use, nor imports, nor substitution in electricity generation at all, that is nothing of the substitutions expected in Table 2 would have materialized. While certainly not a popular option, it might be reassuring to know that this scenario is possible.

A no-substitution-at-all scenario would not be realizable if only the EU did it (savings larger than 100% would be needed).

Some intermediate steps to non-substitution-at-all are shown in Table 5 lines 9-14. All these are very probably overly pessimistic.

4 Observations on Germany

4.1 Overall gas consumption in Germany

Table 6: Gas imports from Russia to Germany

	Eurostat 2019[13]	Eurostat 2020
Gas imports from Russia to Germany	1803 PJ	2045 PJ

[13] Eurostat. “Custom Dataset: Imports of Natural Gas by Partner Country.”, cited previously.

Table 7: Gas consumption in Germany.

	Primary energy gas consumption Eurostat 2019[14]	%	Primary energy gas consumption Eurostat 2020[15]	%	For comparison: Final energy consumption BMWK 2020[16]	%
Households	1118 PJ	32%	1090 PJ	31%	914 PJ	44%
Commercial and public services	440 PJ	12%	463 PJ	13%	353 PJ	17%
Electricity generation (no CHP, public grid)	202 PJ	6%	241 PJ	7%	N.A.	N.A.
Electricity generation (CHP, public grid)	389 PJ	11%	386 PJ	11%	N.A.	N.A.
Industry (including any non-energy use and on-site electricity autogeneration)	1365 PJ	39%	1317 PJ	38%	624 PJ	39%
Transport	7 PJ	0%	6 PJ	0%	7 PJ	0%
Other	0 PJ	0%	0 PJ	0%	N.A.	N.A.
SUM	3502 PJ	100%	3502 PJ	100%	1898 PJ	100%

4.2 Gas consumption in Germany during summer 2021 as a model

Concerns have been raised that the gas network would fail under low gas pressure when the Russian gas imports are removed. However, a low gas consumption scenario, with less than 50% of normal gas consumption, is exercised every summer as can be seen Figure 1. One can clearly see that turning off heating units in summer results in correspondingly lower consumption, that is cutting consumption by more than half in comparison to the winter consumption.

[14] "Eurostat: Custom Dataset: Supply, Transformation and Consumption of Gas.", cited previously.
[15] "Eurostat: Custom Dataset: Supply, Transformation and Consumption of Gas.", cited previously.
[16] Tabellenblatt 6a BMWK. "Zahlen Und Fakten: Energiedaten," 20.Januar, 2022. https://www.bmwi.de/Redaktion/DE/Binaer/Energiedaten/energiedaten-gesamt-xls-2022.xlsx?__blob=publicationFile&v=8

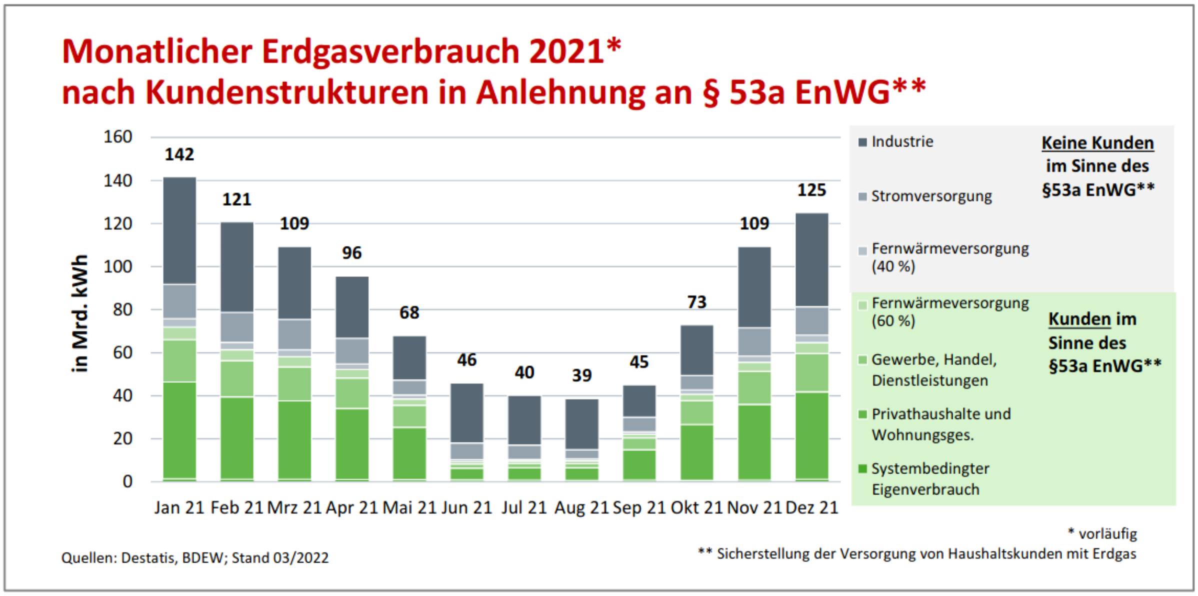

Figure 1: BDEW annual gas consumption[17]: monthly energy consumption in billion kWh in 2021, with industry (in blue) and private consumption (in green).

4.3 Emergency economy scenario for the next winter

Note that if the German populace agrees that turning off the heating in winter would be acceptable (for instance, in the 19th century people did not have access to modern heating and dressed more warmly) if all other means fail, this would be a 100% guarantee to German industry. As space heating has no place in the value chain, cutting down heating would be a purely consumption costs and not cut any productivity.

Again let us emphasize that want to demonstrate that it is possible to secure industry in a scenario where there is no substitution at all. We are aware that in the past, public policy has secured household consumer at the expense of industry. However, in a situation of national crisis, this policy needs to be and can be reversed, by prioritizing industry over households.

However, first, as discussed before, the EU can balance this high savings number by exporting gas from other countries to Germany. We point out that instead of using purely price mechanisms, some sort of rationing might give a better feeling of social justice, which is needed in a national crisis situation. In any case, the enforcement of any strong savings is possibly best *not* left to market forces alone, e.g. a fair distribution mechanism in case of rationing gas at a modest price could be to provide gas in the distribution networks only daily at certain hours (e.g. at noon / evenings) at that price.

[17] BDEW „Fakten und Argumente“, cited previously, page 3; also BDEW. “Monatlicher Erdgasverbrauch in Deutschland 2021 - Vorjahresvergleich.” https://www.bdew.de/service/daten-und-grafiken/monatlicher-erdgasverbrauch-deutschland/

5 Discussion

5.1 Policy implications

The advantage of saving on heating is that heating, unlike industry, typically has an "end consumption" place in the value chain, it is pure consumption and could be avoided by e.g. insulation / warmer clothing.

The given calculations also assume that e.g. France would support Germany with gas (or energy) exports. As we have discussed, it also would be beneficial to include in the cooperation specifically the UK, which is one of the countries itself producing North Sea gas and also with a high savings potential.

For itself, the EU has already stipulated solidarity mechanisms in case of gas supply crisis.[18] The task at hand is to (1) create European solidarity – here e.g. Germany could ask for this in turn for agreeing to energy sanctions (2) convincing public opinion for strong energy savings. For the latter, numerous polls[19] had shown that there was already initially support for energy savings, which the governments should strengthen rather than curb.

For instance, it has to be avoided that switching en masse to electricity for heating endangers the stability of electricity networks. For instance, in the current heat wave in India, electricity outages have been related to cooling turned on by end-users.[20] If in winter consumers who do not have access to gas heating any longer would massively turn on electricity for warm water and space heating instead, then the stability of the electricity grid would suffer, and this again could be bad for industry too. Here appeals to energy savings are needed, e.g. model roles of public ministries such as practiced during the 22 March 2011 cold wave in Tokyo the electricity grid did *not* break down after the government asked for careful heating.[21]

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[18] EU. REGULATION (EU) 2017/1938 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2017 Concerning Measures to Safeguard the Security of Gas Supply and Repealing Regulation (EU) No 994/2010, 2017. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1938&from=DE.

[19] E.g. Brinkmann, Bastian, and Caspar Busse. "Firmen Für Mehr Sanktionen." Süddeutsche Zeitung, April 13, 2022. According to a poll of the German Business Panel (Univ Mannheim) among thousands of companies, a majority of companies is in favor of an energy embargo. In detail, 19% see it "very positive", 22% see it "rather positive", 23% "neutral", 20% "rather negative", and only 16% "very negative". "Importstopp: Mehrheit Unterstützt Energieembargo Gegen Russland, ZEIT ONLINE." Accessed March 12, 2022. https://www.zeit.de/wirtschaft/2022-03/importstopp-russland-gas-oel-energieembargo-umfrage. Deutschland Wählt. "Sollte Deutschland seine Gas-Importe aus Russland stoppen? Ja: 60% Nein: 28% Die aktuellen Sanktionen gegen Russland... Gehen nicht weit genug: 48% Sind genau richtig: 27% Gehen zu weit: 16% via @BILDamSONNTAG / INSA, 1005 online Befragte (04.03.2022)." Tweet. @Wahlen_DE (blog), March 6, 2022. https://twitter.com/Wahlen_DE/status/1500394045507575811 .

[20] Staff, News9. "India Sees Worst Electricity Outage in 6 Years amid Extreme Heatwave; over 13 States Face Power Shortage." NEWS9LIVE, April 29, 2022. https://www.news9live.com/india/india-witnesses-worst-power-shortage-in-over-six-years-due-to-extreme-heat-wave-167313

[21] Welter, Patrick. "Nach Unglück in Fukushima: Japans historischer Stromverzicht ein Vorbild für Deutschland?" FAZ.NET. https://www.faz.net/aktuell/wirtschaft/was-deutschland-von-japans-energieversorgung-lernen-kann-17949554.html.

Putting a strong focus on maintain supplies for industry would also mean that a general prioritization of private consumers as stipulated e.g. in the current German energy law[22] has to be removed, which could be done by legislative act. Industry demands to do this[23] initially had been countered by German Bundesnetzagentur,[24] However, we would follow the argument that consumer savings, which have not been optimized very much in the past, have a much larger potential than industry savings, where we expect that the savings potential is smaller, as price pressure and savings incentive are much higher in industrial installations. The new German campaign on energy savings goes into the right direction.[25] However, for social acceptance, even if results are expected to be less than on the consumer side, industry at least should show also sincere efforts to review its energy usage. Moreover, public administration could be a model for energy savings, as e.g. already practiced in the Netherlands, Italy, German BMWK.[26]

5.2 Technical feasibility of changing gas flows

Gas pipelines from Russia have been shut down e.g. for a few days regularly for system maintenance and a long shut down additionally would mean to seal the gas fields for a longer time (e.g. until the war is over), which technically can be done.[27] It also seems to be easy to reverse the flow of gas, as has been done to provide Poland with gas via the Jamal pipeline after Russia has shut down delivery to Poland on 28 April 2022.[28]

6 Further notes on data and assumptions

Eurostat figures in general are from 2019/2020, which is the newest dataset available. Eurostat UK figures are from 2019 (for UK, the 2020 figures are not yet available). Some nuclear power plants have been shut down in Germany in 2021, which then is however overall balanced by additional renewable energy capacities. As shown in Table 8, we have ignored about 0.5% of gas consumption used for transportation ("T") and about 0.5% gas consumption flared, which are lost in statistical discrepancies ("O"). In sum, all the aforementioned effects appear minor.

Obviously 2020 was the year when COVID-19 hit, so we have mostly focused on 2019 as baseline which of the available data with 7094 PJ of Russian gas imports rather than 6500 PJ of Russian gas imports in 2020, 2019 being the year with the highest imports from Russia ever, so we are maximally pessimistic here. Possibly it also can be observed that the trend to reduce own

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[22] §53a EnWG

[23] Noé, Martin. "Multiaufsichtsrat Karl-Ludwig Kley: 'Gas erst bei den Privaten abschalten, dann bei der Industrie.'" manager magazin, April 27, 2022. https://www.manager-magazin.de/unternehmen/industrie/karl-ludwig-kley-von-eon-und-lufthansa-u eber-gas-embargo-russland-und-handel-mit-china-a-2519cd38-0002-0001-0000-000201341036.

[24] Höning, Antje. "Vorfahrt für Industrie?: Experten warnen vor Gas-Abschaltung der Haushalte." RP ONLINE, April 29, 2022. https://rp-online.de/wirtschaft/experten-warnen-vor-gas-abschaltung-der-haushalte-netzagnetur-chef-klaus-mueller-lehnt-vorfahrt-fuer-industrie_aid-68729191

[25] https://www.energiewechsel.de/

[26] Listing at https://embargo.energy/index.php/Saving/

[27] E.g. see statements by Winterhall Dea speaker Stefan Leunig, in: Pötter, Bernhard. "Öl- und Gasembargo gegen Russland: Nichts in der Pipeline." taz, April 19, 2022, sec. Politik. https://taz.de/!5846266/.

[28] Hosp, Gerald. "Russland dreht den Gashahn zu: Die neusten Entwicklungen." Neue Zürcher Zeitung, May 1, 2022, sec. Wirtschaft. https://www.nzz.ch/wirtschaft/russland-dreht-den-gashahn-zu-die-neusten-entwicklungen-ld.1681268.

production and to rely more on Russian imports has continued in 2021, however this was balanced by a reduction in Q3 2021 due to higher gas prices.[29]

As we have discussed, it also would be beneficial to include in the calculations UK and - to a lesser extent - Ukraine. As for Ukraine, energy saving is certainly not a priority for a country defending itself against an aggressor at war, but actually high gas savings compared to 2019 very likely unfortunately already have been realized by emigration and loss of lives and infrastructure during this war.

Our scenarios overall all also very conservative with asking for high consumer savings, e.g., other substitution scenarios assume that more of half of the gas consumption can be substituted from a combination of substitution by other energy sources, Norwegian, British, Libyan, Dutch and Algerian gas via pipelines and LNG imports and e.g. calculate for an overall savings of 11%[30].

7 Acknowledgment

We greatly acknowledge previous discussions and critical feedback on earlier versions of this document and/or the arguments therein.

[29] BDEW „Fakten und Argumente“, cited, Page 3.
[30] E.g. Dr. Manuel Köhler from Aurora Energy Research https://youtu.be/ab7jFm8CUnU from minute 9 "Halt to Russian gas imports scenario":

8 Appendix: Derivation of industrial use data: Germany and Europe

Table 8 shows how we have grouped the Eurostat data[31]. We did this exercise to make sure that we did not misunderstanding the Eurostat classification. Non-energy use, e.g. as input to chemical processes (overall relatively minor in the 3-4% range) is marked in green. Details on data see https://github.com/hblasum/stop-gas-imports .

Table 8: Assignments to “P“ power , i.e. electricity generation for the public grid, “H” households, “I” industry, “T” transport, “C” commercial / public “O” other, from Eurostat data, in PJ. Here the data is shown for 2020, which we had analysed before coding that into python program, from which also 2019 data has been processed the same way.

		Germany	EU
	Inland consumption - observed	3502	15171
	Inland demand	3502	15171
	Transformation input - energy use	894	4862
P	Transformation input - electricity and heat generation - main activity producer electricity only - energy use	241	1960
P	Transformation input - electricity and heat generation - main activity producer combined heat and power - energy us	386	1571
H	Transformation input - electricity and heat generation - main activity producer heat only - energy use	78	259
I	Transformation input - electricity and heat generation - autoproducer electricity only - energy use	18	107
I	Transformation input - electricity and heat generation - autoproducer combined heat and power - energy use	171	861
I	Transformation input - electricity and heat generation - autoproducer heat only - energy use	0	18
I	Transformation input - blast furnaces - energy use	0	2
O	Transformation input - not elsewhere specified - energy use	0	83
	Energy sector - energy use	80	569
I	Energy sector - electricity and heat generation - energy use	0	4
I	Energy sector - coal mines - energy use	0	0
I	Energy sector - oil and natural gas extraction plants - energy use	7	95
I	Energy sector - coke ovens - energy use	0	1
I	Energy sector - blast furnaces - energy use	0	3
I	Energy sector - petroleum refineries (oil refineries) - energy use	73	451
I	Energy sector - liquefaction and regasification plants (LNG) - energy use	0	9
I	Energy sector - not elsewhere specified - energy use	0	7
O	Distribution losses	0	54
O	Vented	0	0
O	Flared	0	4
	Final consumption	2528	9686
	Final consumption - non-energy use	118	669
	Final consumption - industry sector - non-energy use	118	669
	Final consumption - energy use	2410	9017
	Final consumption - industry sector - energy use	903	3436
I	Final consumption - industry sector - iron and steel - energy use	88	325
I	Final consumption - industry sector - chemical and petrochemical - energy use	261	873
I	Final consumption - industry sector - chemical and petrochemical - non-energy use	118	669
I	Final consumption - industry sector - non-ferrous metals - energy use	36	150
I	Final consumption - industry sector - non-metallic minerals - energy use	114	570
I	Final consumption - industry sector - transport equipment - energy use	35	92
I	Final consumption - industry sector - machinery - energy use	75	252
I	Final consumption - industry sector - machinery - non-energy use	0	0
I	Final consumption - industry sector - mining and quarrying - energy use	4	35
I	Final consumption - industry sector - food, beverages and tobacco - energy use	129	584
I	Final consumption - industry sector - paper, pulp and printing - energy use	86	279
I	Final consumption - industry sector - wood and wood products - energy use	5	22
I	Final consumption - industry sector - construction - energy use	29	86
I	Final consumption - industry sector - textile and leather - energy use	8	74
	Final consumption - transport sector - energy use	22	147
T	Final consumption - transport sector - road - energy use	6	83
I	Final consumption - transport sector - pipeline transport - energy use	16	63
T	Final consumption - transport sector - not elsewhere specified - energy use	0	1
	Final consumption - other sectors - energy use	1486	5434
H	Final consumption - other sectors - commercial and public services - energy use	463	1605
C	Final consumption - other sectors - households - energy use	1012	3654
I	Final consumption - other sectors - agriculture and forestry - energy use	12	167
I	Final consumption - other sectors - fishing - energy use	0	1
O	Final consumption - other sectors - not elsewhere specified - energy use	0	7
O	Statistical differences	-31	54

[31] Eurostat: Custom Dateaset: Supply, Transformation and Consumption of Gas, cited previously. The table itself in editable form is at https://github.com/hblasum/stop-gas-imports/blob/master/data/mapping-of-fine-granular-data.xlsx