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

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(Working draft, feedback welcome!)

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Abstract: Based on current Eurostat energy data available for 2019/2020, 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, and if household / commercial / public consumption gas is saved by 40.5% (which could be entirely taken from heating), gas for electricity generation is 20% substituted, gas for industry is saved by 8%, Russian imports are substituted by 35% from other countries, then this economic entity can do without Russian gas imports.

With a substitution of gas for electricity generation of 54%, even consumer savings of 19% would suffice. Conversely, we also discuss more pessimistic scenarios. As ultimate fallback scenario, one in principle can immediately implement a gas embargo without touching industry consumption or power generation at all, and without additional imports, by a stop on heating and warm water, as the overall consumption of gas by household / commercial / public consumers is larger than the Russian gas imports.

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.

1 Introduction and objective

As of 30 April 2022, the cruel war in Ukraine is being financed by Europe to the extent of more than 47 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 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.

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

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 is one of the very few effective means that can be taken. Even if you disagree and do not wish an 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 only assumes 8% savings in industry to be feasible.[4] 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 gas electricity plants are used for peak load generation. The aforementioned BDEW working paper projected 54% gas savings potential for public electricity generation.[6] For now, given that gas plants are used to balance peak loads, we consider this number high and also assume a more modest reduction for electricity generation.

In the following we show that it is possible to stop immediately Russian gas imports without little (8%) reduction in industry consumption and moderate reduction for public grid electricity generation when gas consumption in the private / commercial / public sectors (also summarized as

[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.

[6] BDEW, cited previously, page 3.

“consumers”, as consumption is mostly used for space heating[7]) is cut down by 40.5% (assuming a rate of substitution in electricity generation of 20%) or 19% (assuming a rate of substitution in electricity generation of 54%). 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 Embargo with reduced gas import balanced by consumers

At Eurostat, the 2021 data is not yet available and the most recent year is 2020 data. However, 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.

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

Table 1 shows Russian imports, Table 2 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, 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 in PJ (petajoule = 10^{15} Joule).

	Eurostat 2019[8]	Eurostat 2020
Gas imports from Russia to Europe	7094 PJ	6500 PJ

As shown in Table 2, the EU has calculated 3247 PJ for realizable short-term (2022) substitution by imports or switching to renewables[9], 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.

[7] For instance, in Germany about 80% of household gas consumption is used for space heating, followed by warm water. BDEW, cited previously, page 18.
[8] 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
[9] 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

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

Item	Bcm	PJ (at 38.2 PJ / bcm[10])
LNG replacements	50	1910 PJ
Pipeline import diversification (e.g. Algeria[11])	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[12]	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", electricity generation for the public grid, 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 6)

	Primary energy consumption Eurostat 2019[13]	%	Primary energy consumption Eurostat 2020	%
Households	5627 PJ	28	5578 PJ	28
Commercial and public services	2032 PJ	10	1955 PJ	10
Electricity generation (public grid)	4622 PJ	23	4550 PJ	23
Industry	7515 PJ	37	7342 PJ	37
Transport	93 PJ	1	90 PJ	0
Other	160 PJ	0	150 PJ	1
SUM	15318 PJ		14670 PJ	

Table 4 shows a scenario where household / commercial / public consumption gas is saved by 40.5%, gas for electricity generation is 20% substituted, gas for industry is saved by 8%. "Old" is the 2019 baseline scenario, "savings" are the savings with above-mentioned savings

[10] 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

[11] 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/.

[12] 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.

[13] "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 .

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 of54 PJ of Belgium can be fed into the deficit of 43 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 811 PJ) and Ukraine (positive contribution 284 PJ), whereas the other non-EU allies' contributions/ needs overall are rather minor.

Table 4: Scenario where 35% of Russian gas imports are diversified, household / commercial / public consumption gas is saved by 40.5%, gas for electricity generation is 20% substituted, gas for industry is saved by 8%. 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 old	Electricity savings	Industry old	Industry savings	Substitution	Balance
Belgium	150	53	151	61	88	36	148	30	318	25	204	54
Bulgaria	91	32	11	5	4	2	29	6	52	4	48	-43
Czechia	364	128	103	42	55	22	48	10	119	9	210	-154
Denmark	0	0	40	16	9	4	19	4	57	5	29	29
Germany	1803	631	1118	453	440	178	592	118	1365	109	1490	-313
Estonia	19	7	8	3	3	1	0	0	6	0	12	-8
Ireland	0	0	27	11	19	8	105	21	57	5	44	44
Greece	65	23	18	7	7	3	127	25	54	4	63	-3
Spain	256	90	161	65	91	37	417	83	750	60	335	79
France	707	247	558	226	278	113	249	50	636	51	686	-20
Croatia	0	0	23	9	10	4	25	5	50	4	22	22
Italy	1274	446	762	309	330	134	973	195	712	57	1140	-135
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0
Latvia	51	18	13	5	5	2	26	5	6	1	31	-20
Lithuania	46	16	11	4	3	1	6	1	67	5	28	-18
Luxembourg	9	3	12	5	5	2	2	0	13	1	11	3
Hungary	689	241	152	62	49	20	73	15	112	9	346	-342
Malta	0	0	0	0	0	0	14	3	0	0	3	3
Netherlands	733	256	318	129	130	53	418	84	618	49	571	-162
Austria	0	0	75	30	17	7	86	17	179	14	69	69
Poland	371	130	177	72	63	25	62	12	413	33	272	-98
Portugal	8	3	13	5	11	5	87	17	122	10	40	32
Romania	37	13	129	52	38	15	65	13	179	14	108	71
Slovenia	4	1	6	3	1	1	4	1	22	2	7	3
Slovakia	260	91	59	24	19	8	28	6	73	6	134	-126
Finland	101	35	11	5	1	1	32	6	37	3	50	-51
Sweden	0	0	1	0	5	2	5	1	34	3	6	6
SUM EU	7038	2463	3959	1603	1681	681	3640	728	6050	484	3496	-1079
Iceland	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
Norway	0	0	1	0	2	1	0	0	258	21	22	22

United Kingdom	0	0	1116	452	305	124	836	167	851	68	811	811
Montenegro	0	0	0	0	0	0	0	0	0	0	0	0
North Macedonia	11	4	1	1	0	0	8	2	2	0	6	-5
Albania	0	0	0	0	0	0	0	0	3	0	0	0
Bosnia and Herzegovina	9	3	4	2	1	0	0	0	4	0	5	-3
Kosovo	0	0	0	0	0	0	0	0	0	0	0	0
Moldova	35	12	14	6	4	2	10	2	5	0	22	-13
Ukraine	0	0	533	216	38	15	128	26	342	27	284	284
SUM Europe	7094	2483	5627	2279	2032	823	4622	924	7515	601	4627	16

2.2 Fallback and alternative scenarios

For a scenario calculation, if we set *imports* (7094 PJ for Europe as per Table 1, 7038 PJ for the EU as per Table 6) 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* (4622 PJ for Europe as per Table 3, 3640 PJ for the EU as per Table 7) to be amount of gas used for electricity generation, *electricity_substitution_rate* the rate for substitution of energy, *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 * electricity_substitution_rate + industry * industry_savings_rate)) / (household + commercial)

Table 7 below applies this formula to calculate fallback and alterative scenarios.

Table 5: Fallback and alternative scenarios

Line number	Section in this document	EU/Europe	Import substitution rate	Electricity substitution rate	Industry savings rate	Substitution amount by previous (PJ)	Still needed substitution (PJ)	Savings rate
1	2.2.1	EU	35.0%	20.0%	8.0%	3675	3363	59.6%
2	2.1	Europe	35.0%	20.0%	8.0%	4009	3086	40.3%
3	2.2.2	EU	35.0%	54.0%	8.0%	4913	2125	37.7%
4	2.2.2	Europe	35.0%	54.0%	8.0%	5580	1514	19.8%
5	2.2.2	EU	45.0%	20.0%	8.0%	4379	2659	47.1%
6	2.2.2	Europe	45.0%	20.0%	8.0%	4718	2376	31.0%
7	2.2.3	EU	35.0%	0.0%	8.0%	2947	4091	72.5%
8	2.2.3	Europe	35.0%	0.0%	8.0%	3084	4010	52.4%

9	2.2.4	EU	0.0%	20.0%	8.0%	1212	5826	103.3%
10	2.2.4	Europe	0.0%	20.0%	8.0%	1526	5568	72.7%
11	2.2.4	EU	0.0%	0.0%	8.0%	484	6554	116.2%
12	2.2.4	Europe	0.0%	0.0%	8.0%	601	6493	84.8%
13	2.2.4	EU	0.0%	0.0%	0.0%	0	7038	124.8%
14	2.2.4	Europe	0.0%	0.0%	0.0%	0	7094	92.6%

2.2.1 EU-only scenarios

As shown in Table 6 and Table 7, also on EU level, almost everywhere cutting off all Russian gas imports could be entirely balanced by household and commercial and public services and a small part of electricity generation. Moreover, the pattern that household + commercial and public sector consumption + electricity generation is larger than Russian imports holds for most European countries, limiting the needs for intercountry flows.

Table 6: Russian gas imports into EU in PJ (petajoule = 10^{15} Joule).

	Eurostat 2019[14]	Eurostat 2020
Gas imports from Russia to EU	7038 PJ	6443 PJ

Table 7: Gas consumption in EU (derivation see Section 6).

	Primary energy consumption Eurostat 2019[15]	%	Primary energy consumption Eurostat 2020	%
Households	3959 PJ	26	3913 PJ	26
Commercial and public services	1681 PJ	11	1605 PJ	11
Electricity generation (public grid)	3640 PJ	24	3531 PJ	23
Industry	6050 PJ	39	5894 PJ	39
Transport	86 PJ	1	84 PJ	1
Other	72 PJ	0	61 PJ	
SUM	15318 PJ	100	14670 PJ	100

Table 7 line number 1 shows an EU-only scenario. Here household / commercial / public consumption gas is saved by almost 60%, gas for electricity generation is 20% substituted, gas for industry is saved by 8%, this is possible when we assume gas exchange within the EU, without

[14] 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

[15] “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 .

any additional imports on the non-EU market. However, the greatly increased savings demands also show that it would be very wise to get other non-EU partners supporting the embargo such as UK and Ukraine to support the measures.

2.2.2 More optimistic scenarios with high electricity generation substitution

Table 7 lines 3 and 4 give a more optimistic scenarios with higher electricity generation substitution of 54% electricity generation substitution as per BDEW (see Section 1). This only would entail energy savings of 19% to European consumers. As another alternative (Table 7 lines 5 and 6) we have calculated a scenario with 45% import substitution (then we would have only 31% consumer energy savings demand). Whether such a high electricity generation / import substitution can be realized remains to be seen.

2.2.3 Scenarios without electricity generation substitution

Table 7 lines number 7 and 8 show scenarios with an electricity generation substitution of 0% instead of 20%. As per Table 2, the growth of renewables (solar, wind, biogas) alone would account for these 20%. However, it could be argued that the growth in electricity generation would still not accommodate the need for peak electricity generation which currently largely uses natural gas. We think the 20% are still justified because at the same time electricity can be generated also from coal, oil (also short-term generation), but show the 0% electricity substitution scenario (which would push up the consumer savings rate up to 53%) for sake of completeness of the possible scenarios.

2.2.4 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 7 lines 9-13. All these are very probably overly pessimistic.

3 Observations on Germany

3.1 Overall gas consumption in Germany

Table 8: Gas imports from Russia to Germany

	Eurostat 2019[16]	Eurostat 2020
Gas imports from Russia to Germany	1803 PJ	2045 PJ

Table 9: Gas consumption in Germany.

	Primary energy gas consumption Eurostat 2019[17]	%	Primary energy gas consumption Eurostat 2020[18]	%	For comparison: Final energy consumption BMWK 2020[19]	%
Households	1118 PJ	32	1090 PJ	31	914 PJ	44
Commercial and public services	440 PJ	13	463 PJ	13	353 PJ	17
Electricity generation (public grid)	592 PJ	17	627 PJ	18	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	
Other	0 PJ	0	0 PJ	0	N.A.	N.A.
SUM	3502 PJ		3502 PJ			

3.2 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.

[16] Eurostat. "Custom Dataset: Imports of Natural Gas by Partner Country.", cited previously.
[17] "Eurostat: Custom Dataset: Supply, Transformation and Consumption of Gas.", cited previously.
[18] "Eurostat: Custom Dataset: Supply, Transformation and Consumption of Gas.", cited previously.
[19] 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

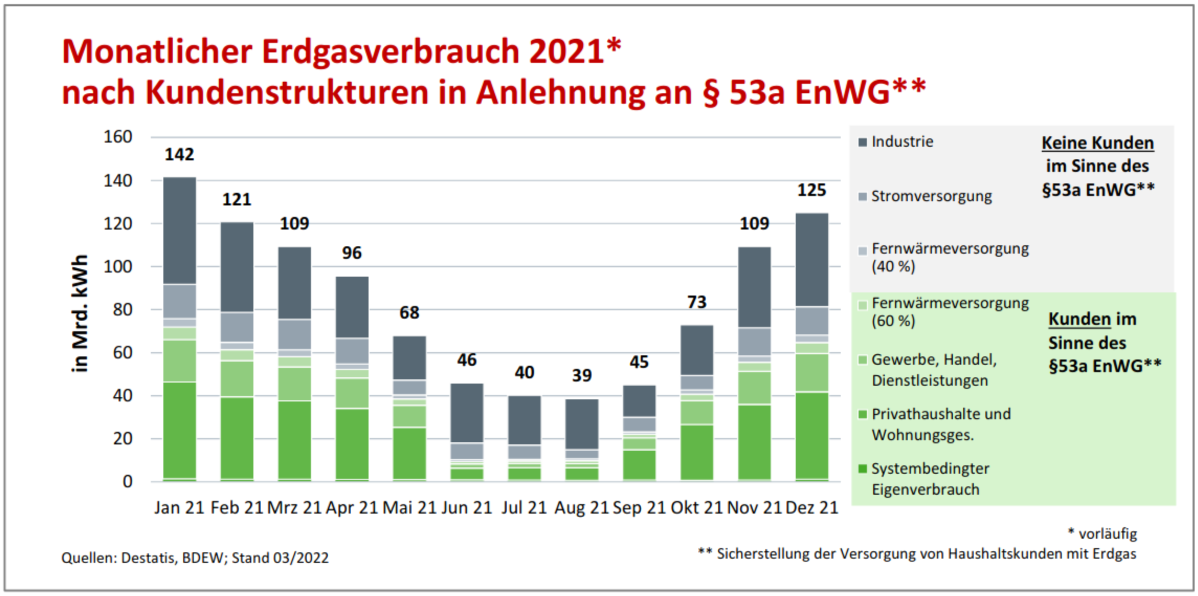

Figure 1: BDEW annual gas consumption[20]: monthly energy consumption in billion kWh in 2021, with industry (in blue) and private consumption (in green).

3.3 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.

[20] 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/

4 Discussion

4.1 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.[21] 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[22] 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. Here appeals to energy savings, e.g. model roles of public ministries such as practiced in Japan in 2011 are needed, e.g. during the 22 March 2011 cold wave in Tokio the electricity grid did *not* break down after the government asked for careful heating.[23] 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[24] has to be removed, which could be done by legislative act.

[21] 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.

[22] 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 .

[23] 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.

[24] §53a EnWG

4.2 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.[25]

5 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 10, 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 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.[26]

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 unforturnately 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%[27].

[25] 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/.
[26] BDEW „Fakten und Argumente", cited, Page 3.
[27] E.g. Dr. Manuel Köhler von Aurora Energy Research https://youtu.be/ab7jFm8CUnU ab Minute 9 "Halt to Russian gas imports scenario":

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

Table 10 shows how we have grouped the Eurostat data[28]. 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 10: 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

[28] 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