Leopoldina
Nationale Akademie
der Wissenschaften

Ad hoc statement | 8 March 2022

Energy alternatives to Russian natural gas in Germany and the rest of Europe

1. The scenario: Russian gas imports stopped

The war against Ukraine has sparked a heated debate surrounding reasonable economic sanctions to be imposed on Russia by the European Union (EU). One measure discussed at length has been a ban on Russian natural gas imports in the EU. Equally, Russia could take the decision to stop supplying natural gas to the EU of its own accord at any point – potentially as a means of retaliation if the scope of the SWIFT sanctions is extended. In both scenarios, Germany would be heavily affected.

This ad hoc statement by the German National Academy of Sciences Leopoldina outlines potential ways of replacing Russian natural gas in Germany and in the rest of the EU in the short and medium term by relying on other – in particular renewable – energy sources. It seems sensible to consider short-, medium- and long-term aspects of substituting Russian natural gas in turn, while always remaining mindful of the geostrategic factors of the medium-term energy transition and the long-term aim of creating a resilient, climate-neutral energy system within Europe.

The statement concludes that even at short notice the German economy could manage a stop of Russian gas imports. Yet bottlenecks would be looming during winter this year. It would be possible, however, to immediately roll out a package of measures aiming to limit the negative repercussions and to mitigate the social impact of these shortages.

2. The current situation: Germany is importing 50 percent of its natural gas from Russia[1]

Natural gas represents over 25 percent of Germany's primary energy consumption, with its main uses lying in industrial processes and private households.[2] Burning natural gas results in fewer CO_2 emissions than burning carbon and petroleum products to produce an equal

[1] Differences in metrics and benchmarks mean that the figures quoted here may differ slightly from other sources.

[2] The data backing up the statements in Section 2 can be found in the following sources: EU Energy in Figures: Statistical Pocketbook (2021, pages 69 and 70) for the 2019 figures and BP Energy Statistics (2021) for the 2020 figures.

amount of energy, making it an important source of energy on the road towards climate neutrality. It was not long ago that the European Commission included natural gas in the EU Taxonomy Regulation as a transition fuel required to allow for the demand for energy in the EU to be reliably and continuously covered and a stability reserve to be built up while efforts are ongoing to achieve the goal of climate neutrality.

In 2019, the 27 EU Member States imported 4,277 terawatt-hours (TWh) of natural gas between them – 945 TWh in the form of liquefied natural gas (LNG) and the rest via pipelines. Of that total, 1,768 TWh came from Russia, with 1,612 TWh imported via pipelines and 156 TWh representing LNG. Germany imported 882 TWh in 2019,[3] just over half of which (450 TWh) came from Russia.[4] The remainder of the natural gas available in Germany amounted to pipeline imports from Norway and the Netherlands, with just a small proportion being extracted in Germany itself.

Germany currently has 51 cavern storage facilities for natural gas with a capacity of 275 TWh (25 billion m^3) between them.[5] That is the equivalent of around 30 percent of its annual consumption. However, the gas storage facilities are currently only around 28 percent full. Over the past decade, they have been between 26 and 78 percent full on 1 March each year.[6] The amount of gas currently in storage could cover the average monthly consumption, bearing in mind that this varies between around 120 TWh in a winter month and around 50 TWh in a summer month.[7]

Given the current situation, Russian natural gas imports ceasing in the EU would involve a phased plan of action in Germany and the rest of Europe consisting of immediate steps, medium-term diversification of energy sources and efforts to incorporate these steps into a credible transformation roadmap guiding us to a sustainable energy supply.

3. Immediate steps: Increase in liquefied gas imports coordinated across the EU and stricter state regulation of the transmission infrastructure as demand for natural gas drops

Liquefied gas imports can replace Russian natural gas in theory...
Liquefied gas from various parts of the world could replace Russian natural gas in areas where gas cannot be substituted altogether at short notice. However, Germany does not have its own LNG terminals as it stands. It can be assumed that it would take at least three years for these to be created despite the fact that plans for three sites are already well underway. While there is the option of importing liquefied gas to Germany via terminals in other countries

[3] Data from: Federal Ministry for Economic Affairs and Climate Action (BMWiK), Energy Data, table 3, see: https://www.bmwi.de/Redaktion/EN/Artikel/Energy/energy-data.html
[4] BP Statistical Review of World Energy 2020, page 43. Figures for 2019. The data represents cubic metres and has been standardised using a gross calorific value of 40 MJ/m^3; therefore percentage share of total amount used.
[5] A subsidiary of the Russian group Gazprom bought gas storage facilities from BASF-Wintershall in 2015 and now holds around 25 percent of Germany's gas storage capacity.
[6] Aggregated Gas Storage Inventory. Link: https://agsi.gie.eu/#/ . This information was incorrect in the first version of this statement but has now been corrected.
[7] BDEW. Link: https://www.bdew.de/service/daten-und-grafiken/monatlicher-erdgasverbrauch-deutschland/

which have seen only rather minimal use over the past few years without any further delay, the conditions that would need to be met are considerable. First of all, the global availability of LNG must be sufficiently high, which ultimately comes down to price, long-term supply agreements and international cooperation. On top of that, a sufficient capacity must be guaranteed when the LNG terminals are connected to the German pipeline grid.

In 2020, the existing LNG terminals in the 27 EU Member States had a joint capacity of 1,715 TWh.[8] Based on the numbers alone, that equates roughly to the 1,768 TWh of natural gas and LNG imported into the EU from Russia as it stands. However, some of this available capacity is already allocated to gas imports. This figure was 798 TWh in 2020.[9] In other words, there would be just under 1,100 TWh available for imports from other parts of the world after Russian gas imports ceased (including 156 TWh of LNG). Turkey also has additional LNG terminals that could help boost the supply of energy to Europe via existing pipelines.

... but transportation capacity is an obstacle to liquefied gas imports

Based on the numbers alone, Russian gas imports ceasing could be largely compensated for at short notice given that the available capacity could cover around 1,100 TWh of around 1,768 TWh currently imported from Russia. However, this rough calculation is actually marking the absolute upper limit because the reality is that the current lack of transportation capacity would stand in the way of this compensation being achieved in full at short notice. In practice, a much smaller proportion would actually be compensated for. For there to be enough energy to cover this year's winter months without any reliance on Russian gas, storage would have to be guaranteed for energy procured throughout the year. With the gas storage facilities in Germany being privately owned, appropriate regulatory measures would be required. Without such measures, the financial risk to be borne by the operators of the storage facilities would be too high. If the gas storage facilities were full, Gazprom could quickly flood the market with cheap gas and cause significant financial damage to European gas importers. If the gas importers were not to fill their storage facilities in anticipation of these low prices, there would be a supply shortage and the prices would be driven up again.

Liquefied gas should be procured by the EU

At the moment, it is just a working hypothesis that Russian natural gas imports may be stopped. However, it would be irresponsible to leave finding a broad substitution for Russian gas imports until after they have been brought to a halt. In fact, it is a matter of urgency that the gas storage facilities are filled as much as possible ahead of the winter months.

In particular, it is now a question of whether the EU acts as quickly as possible to enter the gas market as a serious and coordinated customer – potentially even responding to demands from private gas importers to build up gas reserves – in the face of Russian natural gas imports stopping (a situation that is far from unlikely). After all, the costly process of buying and storing gas is risky for the operators of the storage facilities and, presumably, far from an attractive prospect financially given how precarious the situation is at the moment. There is also reason to be concerned that the gas importers needing to fill their storage facilities to prepare for

[8] International Group of Liquefied Natural Gas Importers, Annual Report 2021, Total Capacity of EU27, pages 55 and 56. Million tons per year converted to TWh at 13.9 TWh/million ton.

[9] International Group of Liquefied Natural Gas Importers, Annual Report 2021, Total LNG Imports of EU27, page 30. Million tons per year converted to TWh at 13.9 TWh/million ton.

potential shortages will become a pawn in Russian exporters' pricing strategy games ahead of Russian natural gas imports ceasing. They might end up sitting on the gas they are purchasing now at extortionate prices while the supply is still forthcoming from Russia. This concern may stop the gas importers from filling their storage facilities. The EU could overcome this dilemma by swiftly developing a joint strategy to increase imports of liquefied gas and reduce the demand for natural gas, thereby allowing for the storage facilities to be topped up as much as possible ahead of the winter.

The structure and usage of the transmission infrastructure could be more strictly regulated by the state

Since the supply of energy can be viewed as an element of state public service, the options for the future infrastructure of the European energy supply system theoretically range from full state control to purely private ownership with state regulation and supervision. It would make sense to avoid any form of micro-management at the very least. Discussions need to be centred around the transmission infrastructure, which consists of energy ports, large-scale storage facilities and transmission grids ("energy motorways"). They could continue to be privately managed but subjected to stricter state regulation in terms of their structure and usage. The other systemic elements of provision, conversion, distribution and usage of energy could continue to be organised privately within a stable and clearly defined state framework.

Reducing the demand for natural gas

Alongside efforts to replace a lack of Russian natural gas imports with imports from other sources, another quick response would be to reduce the demand for natural gas in a number of ways. To start with, natural gas could be replaced with different types of energy, for example by converting more coal into electricity. In such a scenario, greater reliance on coal – a fossil fuel – would not necessarily have a negative impact on climate neutrality targets. The European Emissions Trading System (ETS) sets a cap on how much greenhouse gas pollution can be emitted each year within the electricity and industrial sector. Using more coal as an energy source in the short run would incur extra charges for companies governed by the ETS – and those costs would ultimately be passed on to their customers – but there would not be an increase in European emissions. Steps to boost energy efficiency should also be taken immediately in industrial and domestic settings.

Although quick responses to a lack of Russian gas imports would not hinder efforts to achieve climate neutrality, it is now evident that the costs of this transition will be higher than originally anticipated given the current crisis conditions. Given that the impact of this is most likely to be felt more severely in low-income households, targeted measures to compensate for these effects would be a matter of urgency. A number of suggestions have already been put forward and there is one strategy in particular that would see a standardised price for CO_2 introduced for all sectors, technologies and emitters across Europe in favour of the transition, with most of the income being used to compensate society for the difficulties associated with the transition process.[10]

[10] For more information on this, see German National Academy of Sciences Leopoldina and German Council for Sustainable Development (RNE): Climate neutrality: Options for setting the right course and ambitious delivery. Position paper June 2021 (https://www.leopoldina.org/uploads/tx_leopublication/2021_RNE_Leopoldina_Climate_neutrality_geschuetzt.pdf)

If measures are to have any chance of being rolled out, they really need to be accepted by the general public. The additional costs associated with the procurement of gas on the global market, acceleration of energy-efficiency measures and compensation for households with low to average incomes are affordable. Germany has enough room to manoeuvre in terms of financial policy.

4. Quantitative and qualitative challenges involved with substituting Russian natural gas to generate electricity and heat

When analysing the strategic options for reducing the dependence on Russian natural gas imports in the short, medium and long term, it makes sense to consider electricity and heat generation separately. In Germany, Russian natural gas is used predominantly to produce heat rather than electricity. In terms of an energy balance, substituting gas used to produce electricity with renewable energy and coal is possible in the short to medium term while maintaining the stability and availability of the energy system. When it comes to heat, the industrial heat supply may be limited during cold winters. It is possible, however, that in part production would slow down in some industrial sectors even prior to this owing to the rising natural gas prices, meaning that the overall demand for heat in the industrial sector would drop.

Substituting Russian natural gas used to generate electricity

In 2020, natural gas was used to generate 89 TWh of electricity by means of 174 TWh of thermal energy in Germany.[11] Based on a share of 50 percent alone, Russian natural gas would cover around 45 TWh of that total.[12] Renewable energy sources were used to generate around 230 TWh of electricity in 2020, with 117 TWh of that total coming from wind power. This means that increasing the current capacity to generate electricity from renewable energy sources by just under 40 percent would balance out the situation, but this could only be implemented as a long-term plan.

As it stands, however, using natural gas to generate electricity is the main way of compensating for the considerable fluctuations involved with renewable energy sources. In the long term, this role would have to be taken over by centralised and decentralised power storage facilities and by hydrogen generated using renewable energy sources (and imported) and its reconversion. This would require suitable infrastructures for generating and storing hydrogen as well as transmitting the additional power. This is evidently not a feasible solution in the short to medium term. However, this upgrade will be essential at a later stage on the journey towards a climate-neutral energy supply and it is important to get it underway as soon as possible.

[11] Data from: Federal Ministry for Economic Affairs and Climate Action (BMWiK), Energy Data, tables 22 and 23, see: https://www.https://www.bmwi.de/Redaktion/EN/Artikel/Energy/energy-data.html

[12] Data from the Federal Ministry for Economic Affairs and Climate Action (BMWiK), see: http://www.bmwi.de/Navigation/DE/Themen/energiedaten.html (updated on 31 March 2020)

Quick relief could be provided by replacing the available output from gas power with available output from domestic coal since this would not involve any infrastructure changes.[13] Gas should be substituted with coal immediately to allow for gas supplies to be conserved and built up.

This would, however, slow down the reduction of CO_2 emissions from electricity generation, which is to be achieved primarily by moving away from coal altogether according to the plans to date. 18 Mt CO_2 would have been saved from burning Russian gas in Germany in 2020 (10.4 Mt CO_2 in 2021), but 45 Mt CO_2 would have been emitted by burning German coal instead in 2020 (26 Mt CO_2 in 2021).[14] The high volatility of the figures between 2020 and 2021 is the result of the major price hikes for natural gas.

Since the electricity sector is subject to the ETS, though, the shift towards coal-fired power plants as an alternative to natural gas would not result in more emissions. Within the remit of the ETS, the emissions would just need to be saved elsewhere, which would happen automatically under the emissions trading system. The Fit for 55 package would nevertheless need to be implemented in line with the proposals of the European Commission to avoid climate targets being missed. It is important to remember that the transition to climate neutrality will boost the resilience of the energy supply in Europe in the long term.

In the medium term, it makes sense to stay on track and move away from coal entirely by 2030 and ramp up transformational activities significantly. The shift away from coal will have the added bonus of breaking the dependence on Russian coal (which currently accounts for 50 percent of German coal imports).

Substituting Russian natural gas used to generate heat

Substituting Russian natural gas used to generate process heat and heating energy poses more of a challenge than substituting Russian natural gas used to generate electricity. In the medium to long term, the heating effect of natural gas can be replaced by a combination of renewable energy and hydrogen. However, this will also involve huge volumes of additional energy being generated locally and imported in combination with major upgrades to systems and infrastructures.

In Germany, 210 TWh were used for process heat, 253 TWh were used for heating and hot water in homes and 110 TWh were used to heat industrial and commercial premises in 2020. Just under 300 TWh of the total 573 TWh came from Russia, equating to slightly more than

[13] In principle, nuclear power plants could be made available for this purpose. However, studies in the past (conducted by the likes of the German Federal Ministry for Economic Affairs and Climate Action) have revealed that extending the operating times of nuclear power plants – following on from the long-term preparations that have already been undertaken to power them down – would be very challenging technically and very costly to the economy.

[14] Arbeitsgemeinschaft Energiebilanzen/Umweltbundesamt (Energy Balances Group (AGEB)/German Federal Environment Agency): Entwicklung der spezifischen Kohlendioxid-Emissionen des deutschen Strommix in den Jahren 1990-2018 (Development of specific carbon dioxide emissions from the energy mix in Germany between 1990 and 2018). Federal Environment Agency, 2019. The calculations were based on 1.0 kg/kWh for coal and 0.4 kg/kWh for gas.

50 percent of Germany's gas supply.[15] Generally speaking, gas available on the global market would be used for heating first and foremost because legislation and the "Krisenvorsorge Gas" (Gas Crisis Prevention) guide[16] stipulates that "protected end users" (including domestic customers) are prioritised when it comes to the energy supply. Switching domestic heating systems to electric heat pumps or some other form of electric heating is not an option in the short term.

On that basis, it is most likely that a shortage of gas which could not be compensated for would mean limiting the supply to industrial facilities. In one realistic scenario, all the requirements of industrial production would be met during the summer months while considerable restrictions would be imposed on industrial production in the winter once Germany's gas storage facilities would be emptied, considering that they can cover the entire demand for around 90 days when full to start with. Logic dictates that this sort of shortage needs to be overcome by filling and maintaining the storage capacity as quickly as possible in the short term and by extending the storage capacity in the medium term. With immediate effect, all the energy-efficiency measures which allow for the storage facilities to be topped up need to be taken during the summer months when there is plenty of gas by comparison.

5. Energy security in the long term

On the whole, it is not possible to replace Russian natural gas swiftly and specifically with domestic renewable energy and recoverable hydrogen. This shift will indeed be required towards the end of the energy system transition, but current thinking suggests that the necessary efforts should not be ramped up significantly until coal has been abandoned once and for all. Realistically, it will be possible to move away from natural gas altogether as soon as large enough volumes of hydrogen can be made available while keeping the CO_2 emissions to a minimum. Only a minimal proportion of this hydrogen can be provided nationally if renewable energy sources are to primarily cover the electricity supply.

It is also essential to consider the financial consequences of shifts in demand on the global gas market. The shortage of natural gas on the global markets owing to greater demand for gas in holders will presumably result in significant and prolonged price rises. In light of these developments, it makes even more economic sense to expedite efforts to create a regionally diversified global market for green energy sources based on hydrogen.

6. Conclusion

The current situation is calling for a more proactive approach to restructuring the energy system than ever before. This can be achieved by following two tracks simultaneously – the diversified internationalisation of supply and the gradual replacement of energy sources.

[15] Data calculated using BMWiK Energy Data, tables 7a and 7b, see: https://www.https://www.bmwi.de/Redaktion/EN/Artikel/Energy/energy-data.html
[16] BDEW/VKU and others, Krisenvorsorge Gas (Gas Crisis Prevention). Berlin, 2021.

The political, legislative and economic framework conditions for stakeholders in the future energy system need to be set out at the European level. National structures can only be feasibly planned within the European context. The EU Member States whose energy supplies are currently highly dependent on Russia should lead the way, but the EU must be considered as a whole in any plans from the outset. The recommended measures to be taken can be divided into three phases:

Immediate steps (over the next few weeks and months)

- Procurement of liquefied gas on the global market by the EU, including negotiations with countries such as Japan, the USA and South Korea
- Stricter state regulation of the structure and usage of privately managed transmission infrastructures
- Replacement of gas with coal in the electricity sector and procurement of the coal required
- Immediate efforts to save on gas and fill the storage facilities as winter reserves
- Coordination of action at the EU level
- Checks on compatibility of emergency measures with existing market mechanisms
- Compensation for households with low and average incomes and energy tax relief for businesses

Medium-term action (within one year)

- Procurement of a robust reserve of energy sources
- Expansion of capacity to receive LNG and integration of sufficient LNG terminals in supply grids
- Potential long-term suitability of infrastructure as part of LNG expansion for switch to hydrogen ("H_2-ready")
- Gas grid upgrade to allow for more diverse entry points

Long-term measures (over the next 2–10 years)

- Acceleration of efforts to achieve climate neutrality, especially by means of:
    - Infrastructure expansion with a focus on handling hydrogen and its derivatives
    - Hydrogen imports
    - Development of renewable energy sources
- Confirmation of compatibility of transformation roadmap with new framework conditions (especially high gas prices in the long term)

The German government has already started making critical decisions, as demonstrated by the purchase of gas for 1.5 billion euros and the planned regulation on filling the gas storage facilities. Given the current situation, it is important not to lose sight of the plan to abandon coal altogether by 2030. This will also help remove the dependence on Russian coal imports, which currently account for 50 percent of Germany's total.

Existing successful mechanisms aimed at reducing greenhouse gas emissions, especially the European Emissions Trading System and its development under the EU Green Deal, must not

be neglected. After all, it is exactly these mechanisms that provide a solid foundation for further accelerating action.

Authors

Prof. Dr. Robert Schlögl ML, Fritz Haber Institute of the Max Planck Society and the Max Planck Institute for Chemical Energy Conversion, Mülheim/Germany
Prof. Dr. Ferdi Schüth ML, Max-Planck-Institut für Kohlenforschung (Max Planck Institute for Coal Research), Mülheim/Germany
Prof. Dr. Antje Boetius ML, Helmholtz Centre for Polar and Marine Research, Alfred Wegener Institute, Bremerhaven/Germany
Prof. Dr. Ottmar Edenhofer ML, Potsdam Institute for Climate Impact Research, Potsdam/Germany and Mercator Research Institute on Global Commons and Climate Change, Berlin/Germany
Prof. Dr. Veronika Grimm, FAU (Friedrich-Alexander-Universität) Erlangen-Nürnberg/Germany
Prof. Dr. Sibylle Günter ML, Max Planck Institute for Plasma Physics, Garching/Germany
Prof. Dr. Gerald Haug ML, German National Academy of Sciences Leopoldina
Prof. Dr. Jochem Marotzke ML, Max Planck Institute for Meteorology, Hamburg/Germany
Prof. Dr. Wolfgang Marquardt ML, Forschungszentrum Jülich (Jülich Research Centre) Jülich/Germany
Prof. Dr. Christoph M. Schmidt ML, RWI – Leibniz Institute for Economic Research, Essen/Germany
Prof. Dr. Ulrich Wagner, Technical University of Munich and Forschungsstelle für Energiewirtschaft (Research Institute for Energy, FfE) Munich/Germany

Editorial support

Dr. Christian Anton, German National Academy of Sciences Leopoldina, Science-Policy-Society Department
PD Dr. Stefan Artmann, German National Academy of Sciences Leopoldina, Presidential Office

ML = Member of the Leopoldina