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Monitoring the security of gas supply in the European Union

Fernández-Blanco Carramolino, R., Schill, R., Costescu, A., Vuillaume, J.-F., Jung, D., Calisto, H., Ichaso Franco, J., Lo Presti, L., Pozo Cámara, D., Rodríguez Gómez, N., Bolado Lavín, R.

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Joint Research Centre

EUR 31647 EN

Contact information
Name: Ricardo Bolado Lavín
Address: Westerduinweg 3, 1755LE Petten, Netherlands
Email: ricardo.bolado-lavin@ec.europa.eu
Tel.: +31 224 565349

EU Science Hub
https://joint-research-centre.ec.europa.eu

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Contents

Abstract

In late 2021, an energy crisis emerged in the European Union (EU) as a result of (i) high energy prices following the summer season and (ii) various geopolitical and technical events. These circumstances had an impact in the operation of the EU's natural gas system and the security of gas supply of the EU was threatened. During 2022, three different regulations were adopted in record time to safeguard the security of gas supply in the EU. They are related mainly to imposing minimum levels of gas in underground gas storages (UGSs) at the beginning of the winter, recommending demand reduction measures on a voluntary basis, and enhancing solidarity through better coordination of gas purchases. As a consequence, the need for monitoring the natural gas system as closely in time as possible increased during the energy crisis.

In this context, the Joint Research Centre (JRC) monitored the operation of the EU natural gas sector, including UGSs, liquefied natural gas (LNG) regasification terminals, and transport of gas via pipeline. This monitoring is carried out daily and weekly with three publicly available data platforms that collect natural gas-related information. First, the European Network for Transmission System Operators for Gas (ENTSOG) manages a Transparency Platform (TP) containing gas transport indicators. Second, Gas Infrastructure Europe (GIE) collects information about UGSs by means of its Aggregated Gas Storage Inventory (AGSI+). Third, GIE also provides indicators for the large-scale LNG terminals via its Aggregated LNG Storage Inventory (ALSI). In addition, the in-house ENaGaD database provides daily natural gas consumption by member state and broken down by sector for some countries. The main goals of this report are twofold: (i) it examines the operation of the EU natural gas system in 2022 and compares it to historical records, and (ii) it presents tools for monitoring daily the EU's natural gas system operation using public transparency platforms.

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Authors

Fernández-Blanco Carramolino, Ricardo (JRC.C.3)

Schill, Rebecca (JRC.C.3)

Costescu, Anca (JRC.C.3)

Vuillaume, Jean-François (JRC.C.3)

Jung, Daniel (German Aerospace Center - DLR, Institute of Networked Energy Systems, Oldenburg, Germany)

Calisto, Hugo (TEMA – Centre for Mechanical Technology and Automation, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro Portugal)

Ichaso Franco, José (JRC.C.3)

Lo Presti, Luisa (JRC.C.3)

Pozo Cámara, David (JRC.C.3)

Rodríguez Gómez, Nuria (JRC.C.3)

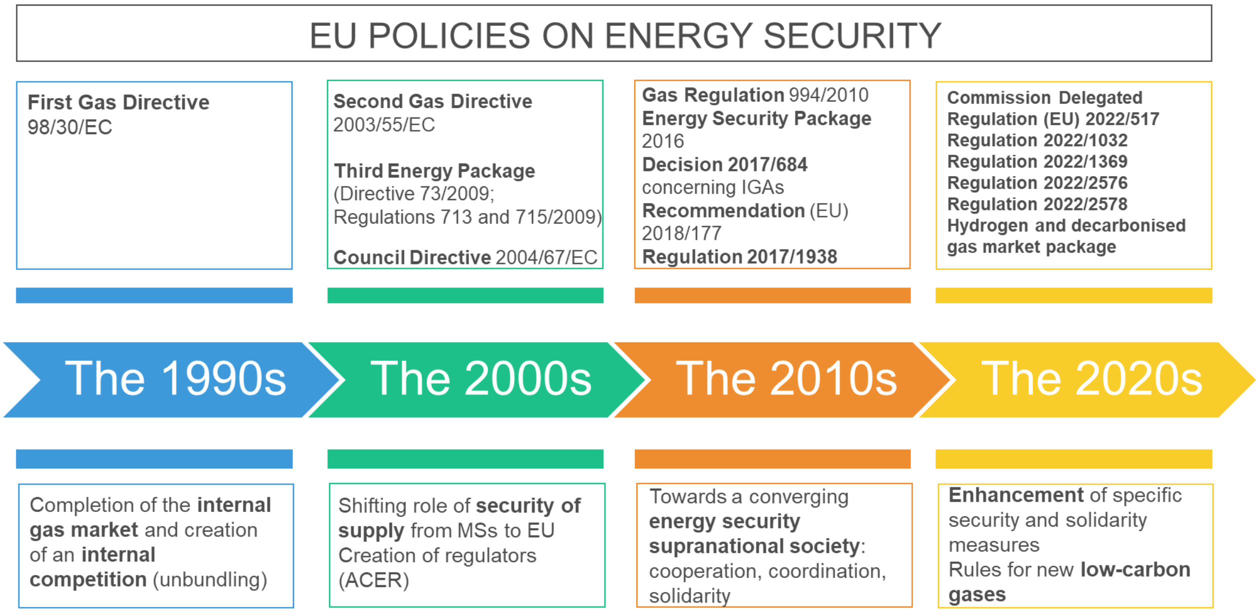
Bolado Lavín, Ricardo (JRC.C.3)

1 Introduction

More than 20 years ago, the International Energy Agency (IEA) defined *energy security* as "*the physical availability of supplies to satisfy demand at a given price*" (IEA, 2001). This definition encompasses both quantity and price risks, and energy market shocks can be caused by short-term or long-term components. A continuous price increase of energy imports could have different consequences than a sudden price hike, as indicated in (IEA, 2001). This definition is applicable to the natural gas sector in the European Union (EU). Various composite indicators have been proposed in the technical literature to assess the multi-dimensional concept of security of gas supply (Badea, Rocco, Tarantola, & Bolado, 2011). The four dimensions include availability of resources, accessibility, acceptability (environmental implications), and affordability. This report focuses on the first dimension, i.e. the availability of resources.

Since the commercial dispute between Ukraine and Russia in January 2009, security of gas supply has been a primary focus of the EU's energy policy agenda (Rodríguez-Gómez, Zaccarelli, & Bolado-Lavín, 2016). This concern was underscored by several legislative initiatives, including Regulation (EU) No 994/2010, the European Energy Security Strategy in May 2014, and the third energy package for electricity and gas markets, all with the common goal of strengthening the security of gas supply of the EU. Figure 1 presents an overview of the EU policies on energy security since the 1990s until the current decade. The last 30 years of energy security policies on natural gas is summarised by Sesini, Giarola, & Hawkes (2022).

Figure 1. Evolution of the European Union policies on energy security.



(*) EC stands for European Commission and IGA for Inter-Governmental Agreements.

Source: JRC adaptation of the diagram from (Sesini, Giarola, & Hawkes, 2022) .

In the aftermath of the Ukraine-Russia dispute in 2014, the Regulation (EU) 2017/1938 ([1]) became the reference legal text for safeguarding the security of gas supply. It provides a comprehensive framework for the preparedness and resilience of EU natural gas markets in case of potential gas disruptions. This regulation promotes cooperation between EU countries, development of common risk assessments and of joint preventive action and emergency plans, permanent bidirectional capacities on all cross-border interconnectors in the EU, adoption of solidarity mechanisms to protect vulnerable consumers, and the performance of an EU-wide gas supply and infrastructure disruption simulation by the European Network of Transmission System Operators for gas (ENTSOG).

In the fall of 2021, the European gas market was impacted by various geopolitical and technical events, resulting in a price hike during the last quarter of the year (Fernández-Blanco Carramolino, Giaccaria,

([1]) 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 (europa.eu).

Costescu, & Bolado-Lavín, 2022; ACER, 2021). Gas price hike accompanied with volatility periods persisted and further increased in 2022, prompted by the Russian invasion of Ukraine on 24 February 2022. These developments have marked the beginning of a new paradigm in the EU's energy policy, particularly in the context of security of supply, as the region seeks to address the challenges posed by these events. In Figure 1, we can observe a more active political agenda on energy security of supply in the first three years of the 2020s compared to the last three decades, with the adoption of four regulations in 2022 and the ongoing discussion of the hydrogen and decarbonised gas market package released on 15 December 2021 ([2]).

These regulations have been preceded by several communications. The first one was the European Commission (EC) communication to tackle rising energy prices on 13 October 2021 ([3]). The EC adopted a set of measures to mitigate the price impacts on vulnerable consumers and small businesses, and a set of actions to incentivise a decarbonised and resilient energy system. Several months later, the REPowerEU plan was released on 18 May 2022 which proposes to end Europe's energy dependence with Russia before 2030 ([4]) by implementing the following measures: (i) diversification of gas supplies (liquefied natural gas - LNG - and pipeline, increase of EU biomethane production, and boost of hydrogen supply chain), (ii) roll-out of solar, wind and heat pumps, and (iii) the industry decarbonisation, among others.

The energy policy developments related to the security of gas supply in 2022 can be summarised in three main regulations as follows:

— Regulation (EU) 2022/1032 of the European Parliament and of the Council of 29 June 2022 amending Regulations (EU) 2017/1938 and (EC) No 715/2009 with regard to gas storage. This regulation specifically on underground gas storage (UGS) facilities was published on 23 March 2022 ([5]). Minimum storage obligations were proposed to ensure security of energy supply, i.e., 80% on 1 November 2022 and rising to 90% from 2023 onwards. The political agreement on this proposal between the European Parliament and EU Member States (MSs) was reached on 19 May 2022 ([6]) and the measures were adopted in the new Gas Storage Regulation (EU) 2022/1032 on 30 June 2022 ([7]). Apart from the minimum storage obligations, this legislative act contains provisions on the certification of storage system operators (SSOs). The JRC report by Fernández-Blanco Carramolino et al. (2023) explains exhaustively the implementation of the regulation and the most important articles related to the minimum storage filling levels (Fernández-Blanco Carramolino, Rodríguez-Gómez, & Bolado-Lavín, 2023). On 23 November 2022, the Commission Implementing Regulation (EU) 2022/2301 setting the filling trajectory with intermediary targets for 2023 ([8]) for each MS was adopted to ensure gas supplies for the winter 2023-2024.

— Regulation (EU) 2022/1369 on coordinated demand reduction measures for gas was adopted on 5 August 2022 ([9]). This legislative tool was first announced on 20 July 2022 in the communication "save gas for a safe winter" for economic and security reasons ([10]). The purpose was to ease the burden on the economy by proposing coordinated measures as well as help reach the storage target filling level of 80% on 1 November 2022. This regulation essentially recommends a voluntary reduction target of 15% at EU level compared to the reference average consumption during the period 1 August 2022 – 31 March 2023. In case there is a significant deterioration of the gas supply situation in the European Union due to (i) a

([2]) Directive COM(2021) 803 final - Directive on common rules for the internal markets in renewable and natural gases and in hydrogen, Brussels, 15 December 2021.

([3]) Communication COM(2021) 660 final - Tackling rising energy prices: a toolbox for action and support, Brussels, 13 October 2021.

([4]) Communication COM(2022) 108 final - REPowerEU: Joint European Action for more affordable, secure and sustainable energy, Strasbourg, 8 March 2022.
Communication COM(2022) 230 final - *REPowerEU Plan*, 18 May 2022.

([5]) COM(2022) 135 final - Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2017/1938, Brussels, 23 March 2022.

([6]) "Commission welcomes political agreement on new rules for securing winter gas storage," [Online]. Available: https://ec.europa.eu/info/news/commission-welcomes-political-agreement-new-rules-securing-winter-gas-storage-2022-may-19_en. [Accessed 25 May 2022].
"Gas storage: Council and Parliament reach a provisional agreement," [Online]. Available: https://www.consilium.europa.eu/en/press/press-releases/2022/05/19/gas-storage-council-and-parliament-reach-a-provisional-agreement/. [Accessed 25 May 2022].

([7]) Regulation (EU) 2022/1032 of the European Parliament and of the Council of 29 June 2022 amending Regulations (EU) 2017/1938 and (EC) No 715/2009 with regard to gas storage, Official Journal of the European Union, 30 June 2022.

([8]) Commission Implementing Regulation (EU) 2022/2301 of setting the filling trajectory with intermediary targets for 2023 for each Member State with underground gas storage facilities on its territory and directly interconnected to its market area, Official Journal of the European Union, 23 November 2022. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022R2301.

([9]) Council Regulation (EU) 2022/1369 on coordinated demand-reduction measures for gas, Official Journal of the European Union, 5 August 2022.

([10]) COM(2022) 360 final - Save gas for a safe winter, Brussels, 20 July 2022.

substantial risk of severe gas supply shortage, or (ii) an exceptionally high demand for gas, then the declaration of Union Alert can be triggered. The Union Alert, which can also be declared if five or more competent authorities issue an alert at national level, means that the voluntary gas demand is not sufficient but there is no need to resort to non-market-based measures. Therefore, the voluntary demand reduction becomes mandatory. Demand reduction can be viewed as a preventive / mitigative measure; preventive because the energy voluntarily saved during summer, and possibly winter, could help avoid getting into a scenario of gas curtailment during winter; mitigative because the enforced demand reduction would certainly mitigate the consequences of such a scenario should it occur. On 20 March 2023, it was proposed to prolong the demand reduction regulation for one additional year starting on 1 April 2023 ([11]). This proposal changes the duration of the reduction period to be spread over one year instead of eight months (from 1 April 2023 until 31 March 2024) in order to facilitate the refilling of storages during the summer. In addition, there is an improvement in the provisions about monitoring and reporting of gas consumption by increasing the reporting frequency and the data quality.

— Regulation (EU) 2022/2576 of 19 December 2022 enhancing solidarity through better coordination of gas purchases, reliable price benchmarks and exchanges of gas across borders ([12]). One of the chapters of this non-permanent regulation is specifically related to gas emergency. Articles 23-25 contain provisions on gas solidarity, whereas articles 26-28 are devoted to harmonise solidarity mechanisms among EU MSs in case of lack of agreement. The former articles create the conditions to request and provide solidarity. It is relevant the definition for the first time of the critical gas volumes for electricity security of supply, thus highlighting the importance of the interdependence of the EU natural gas and electricity sectors. The latter articles 26-28 refer to default rules for solidarity measures in an emergency event in case no solidarity agreement is in place. This is crucial because there are only seven bilateral solidarity agreements ([13]) in the EU to date, out of approximately 40 that should have been signed after the adoption of the Regulation (EU) 2017/1938 and of Commission Recommendation (EU) 2018/177 on the elements to be included in the technical, legal and financial arrangements between MSs for the application of the solidarity mechanism. This underlines how difficult it is to agree on specific arrangements to provide solidarity gas. Finally, the development of a joint procurement platform of reserve gas stocks was established on 7 April 2022 by which EU countries are obliged to aggregate demand for volumes of gas equivalent to 15% of their respective storage filling obligations. One year later, the first call for companies to jointly buy gas was launched for the 2023 storage filling season ([14]).

Several days after the Regulation on enhancing solidarity, the Regulation 2022/2578 establishing a market correction mechanism ([15]) was adopted and it contains safeguards to ensure the EU's security of gas supply. This legislative act is not primarily focused on security of supply; it limits gas price spikes and ensures market stability to protect citizens and the economy as a whole against high energy prices.

Since the beginning of the energy crisis in autumn 2021, the Joint Research Centre (JRC) of the EC has monitored very closely the operation of the EU natural gas system by analysing the evolution of key indicators related to the EU's security of gas supply. Thanks to this work, the JRC has provided technical and scientific support to the Directorate-General for Energy (DG ENER) on a daily, and even weekly, basis. The daily monitoring of the gas network operation relies on publicly available data platforms:

— The ENTSOG Transparency Platform (TP) collects gas transport indicators (e.g., physical flows, nominations, gross calorific values – GCVs , etc) with daily and even hourly resolution.

— The Aggregated Gas Storage Inventory TP (AGSI+ TP), which is managed by Gas Infrastructure Europe (GIE), collects information on European UGS facilities with daily resolution.

— The Aggregated Liquefied Natural Gas Storage Inventory (ALSI) TP, which is also managed by GIE, provides information on large-scale LNG terminals in the EU.

(11) Council Regulation amending Regulation (EU) 2022/1369 as regards prolonging the demand reduction period for reduction measures for gas and reinforcing the reporting and monitoring of their implementation, Official Journal of the European Union, 30 March 2023. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0174.

(12) Council Regulation (EU) 2022/2576 - Enhancing solidarity through better coordination of gas purchases, reliable price benchmarks and exchanges of gas across borders, Official Journal of the European Union, 19 December 2022. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2022.335.01.0001.01.ENG.

(13) Seven bilateral solidarity agreements has been signed by 16 May 2023: Germany-Denmark, Germany-Austria, Latvia-Estonia, Latvia-Lithuania, Italy-Slovenia, Estonia-Finland, Denmark-Sweden.

(14) https://energy.ec.europa.eu/topics/energy-security/eu-energy-platform_en.

(15) Council Regulation (EU) 2022/2578 - Establishing a market correction mechanism to protect Union citizens and the economy against excessively high prices, Official Journal of the European Union, 22 December 2022. EUR-Lex - 32022R2578 - EN - EUR-Lex (europa.eu).

To a lesser degree, other publicly available data sources could be used to monitor the natural gas network in the mid-term such as Eurostat or the JRC database ENaGaD (for gas consumption data) because their updates are less often than the ones done by ENTSOG and GIE (the key indicators are updated every day with a maximum of two-day delay). Moreover, resorting to privately-owned databases is also possible to complement the public information, e.g., IHS Markit provides data on LNG imports/exports worldwide. The JRC report (Jung, et al., 2022) thoroughly describes the python package tool developed to monitor the EU's security of gas supply and facilitate the download, essentially, of the transport data provided by ENTSOG Transparency Platform.

The objectives of this report are twofold:

— The analysis of the operation of the European Union's natural gas system in 2022 compared to its recent past. Several aspects are discussed throughout the report: (i) the low utilisation of Gazprom-related storage sites during 2021 and the refilling of those storages during 2022 after the adoption of the new Gas Storage Regulation, (ii) the increased usage of gas in liquid form making LNG one of the main suppliers in the European Union, (iii) changes in physical flows by comparing old and new paradigms, and (iv) the impact of the current status quo on the demand side.

— The presentation of the monitoring tools to track changes in the operation of the natural gas system on a daily basis. The report covers the operation of underground gas storages, LNG facilities, and cross-border physical flows (with third countries and within EU countries).

The report is organised as follows. The first dimension of the report, i.e. the analysis of the EU's natural gas system operation in 2022, is covered in Sections 2-5, while the second dimension, i.e. the presentation of monitoring tools, is described in Section 7.

Section 2 provides the information about the UGS sites in the EU in terms of filling levels, gas in storage, as well as gas injected/extracted. This section also discusses the evolution of Gazprom-related storages in 2021 and 2022. Section 3 covers LNG data at European, country, and facility levels, with a focus on the inventory level of LNG storages, send-out physical flows, and LNG send-out utilisation. Section 4 is focused on the transport data of the EU's natural gas network by looking at physical flows and utilisation factors of pipelines connected to non-EU countries and intra-EU pipelines. Section 5 is devoted to analysing the gas consumption in the EU. Section 6 presents the graphic tools for monitoring the security of gas supply in the EU on a daily basis. Section 7 provides some concluding remarks about the operation of the natural gas system in 2022 and the challenges faced to monitor it adequately. Finally, a series of annexes provide some tabular data of the presented figures.

2 Underground gas storage

UGS data is publicly available at the AGSI+ TP ([16]). The platform provides data on UGS at EU level plus United Kingdom (UK) and Ukraine (UA). This is a transparency initiative by Gas Infrastructure Europe (GIE) whose members publish UGS data on a voluntary basis per Member State, storage operator, and storage site since 2011. As acknowledged by GIE, this initiative helps to provide the information the market needs to operate efficiently and effectively while protecting commercially sensitive information.

There are 18 EU MSs with UGS providing information to the platform on a daily basis, namely Austria (AT), Belgium (BE), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), France (FR), Germany (DE), Hungary (HU), Italy (IT), Latvia (LV), Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Spain (ES), and Sweden (SE). Furthermore, two non-EU countries send gas storage data to GIE, namely UK and UA. Serbia (RS) is also displayed in the list but there is no publicly available data in the platform.

We download the required gas storage data on a daily or weekly basis through the offered API service (Application Programming Interface) by using the python requests module ([17]). The API provides quick, continuous, and direct access to the database and allows to filter, create queries and export the data as required. It is also important to download the data frequently because corrections are periodically implemented. Data is then processed in Python 3.7 with a Jupyter notebook ([18]) and the corresponding visualisation and data management libraries.

The aggregated UGS data at EU level from the TP also contains information about UK UGSs from 1 May 2012 until 30 December 2020 categorised as “Pre-Brexit”. Therefore, we need to adjust the values accordingly to account only for EU UGSs, i.e., excluding UK (Pre-Brexit) from the corresponding aggregated data.

The data provided in the transparency platform for each individual UGS facility or group, company and/or country are the following:

- Gas in storage in TWh: Total amount of gas in storage.
- Filling level in %, which is computed as the gas in storage divided by the working gas volume and multiplied by 100.
- Trend in %, which is computed as the difference between injections and withdrawals divided by the working gas volume and multiplied by 100.
- Injection in GWh/d.
- Withdrawal in GWh/d.
- Working gas volume in TWh: Maximum amount of gas that can be stored at the facility.
- Injection capacity in GWh/d: Technical injection capacity.
- Withdrawal capacity in GWh/d: Technical withdrawal capacity.
- Data quality status, which can be estimated, confirmed, or no data.

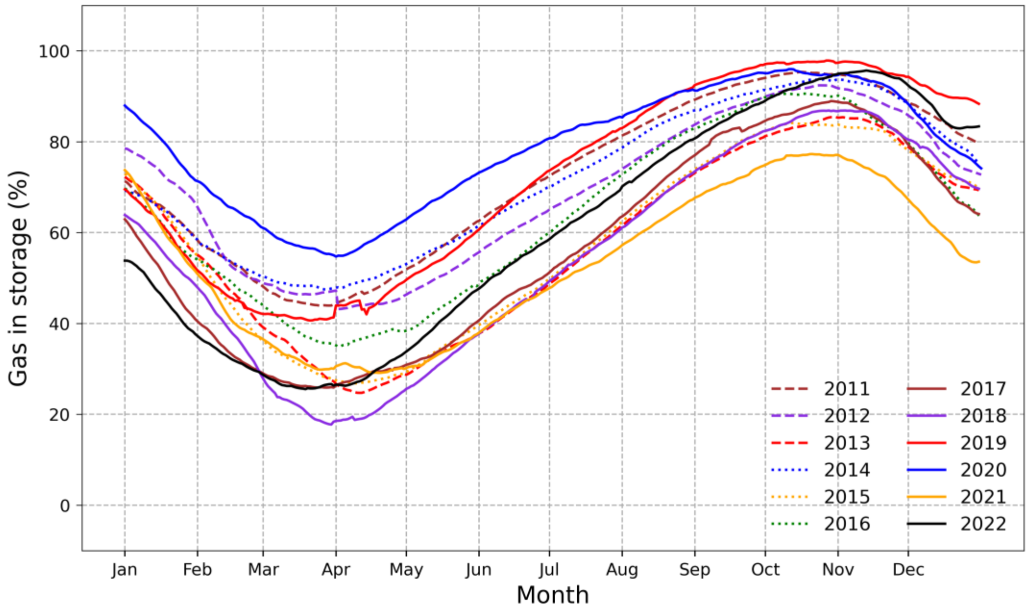
Since 2022, reported data have been extended to include the annual consumption by country in energy units and the filling level compared to annual consumption in percentage. In addition, GIE is progressively updating its transparency platforms following Council Regulation (EU) 2022/2576 and inputs as received from SSOs. Hence, new data fields can be seen in AGSI+ TP such as the contracted, available and covered capacity. The contracted capacity is defined as the capacity already booked at the storage facility for the current gas storage year. The available capacity is the capacity still available at the storage facility for the current gas year. This information can be seen only at storage facility level. As announced in the TP, according to Article 13(2) of Council Regulation (EU) 2022/2576, SSOs should, by 31 January 2023, make public tariffs for storage capacity products offered to the market. The actual tariffs are not made directly available by AGSI+ TP, which instead provides the links to the relevant websites where such information can be retrieved.

([16]) https://agsi.gie.eu/#/.
([17]) https://docs.python-requests.org/en/latest/.
([18]) https://jupyter-notebook.readthedocs.io/en/stable/notebook.html.

2.1 Gas storage filling level in the European Union

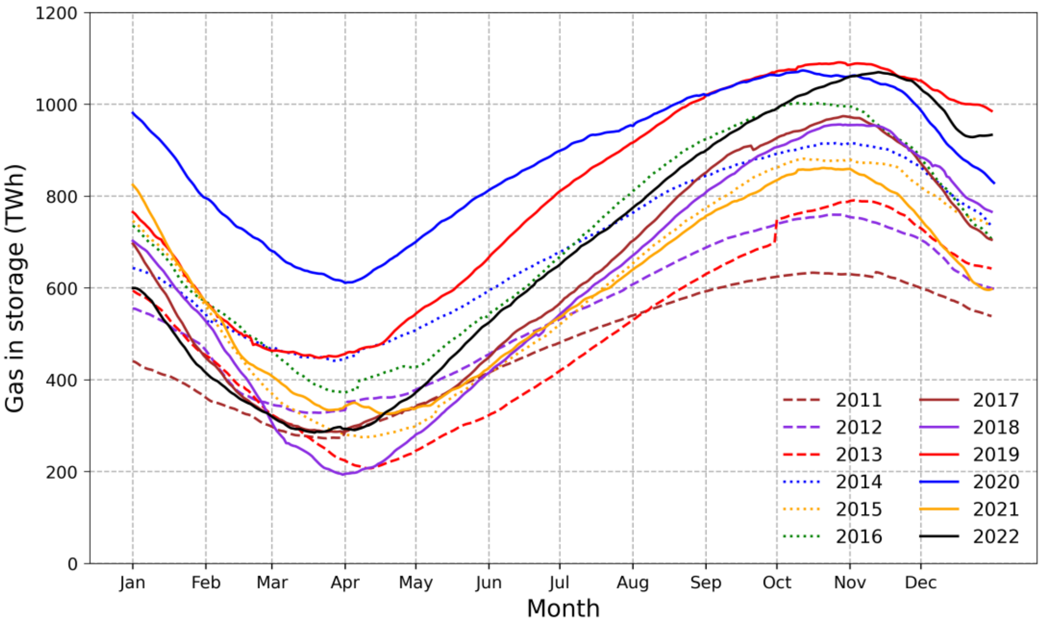
Figure 2 and Figure 3 represent the gas storage evolution in the European Union in the last 12 years (2011-2022) in relative and absolute terms, respectively. In relative terms, we observe that the gas in storage level during the second half of 2021 and beginning of 2022 was the lowest since 2011 and, in absolute terms, since 2014. This trend continued for the first two months of 2022, being even lower in absolute values than the gas stored during years 2012 and 2013. In spite of the low level of gas in storage during the first quarter of 2022 and the high energy prices, the gas in storage at the beginning of the heating season (95.0% on 1 November 2022) was the second highest of the last 12 years, being just lower than the filling level in 2019 (97.4%).

Figure 2. Gas storage filling level (%) in the European Union in the last 12 years (2011-2022).



Source: JRC based on AGSI+ Transparency Platform, 2023.

Figure 3. Gas in storage level (TWh) in the European Union in the last 12 years (2011-2022).

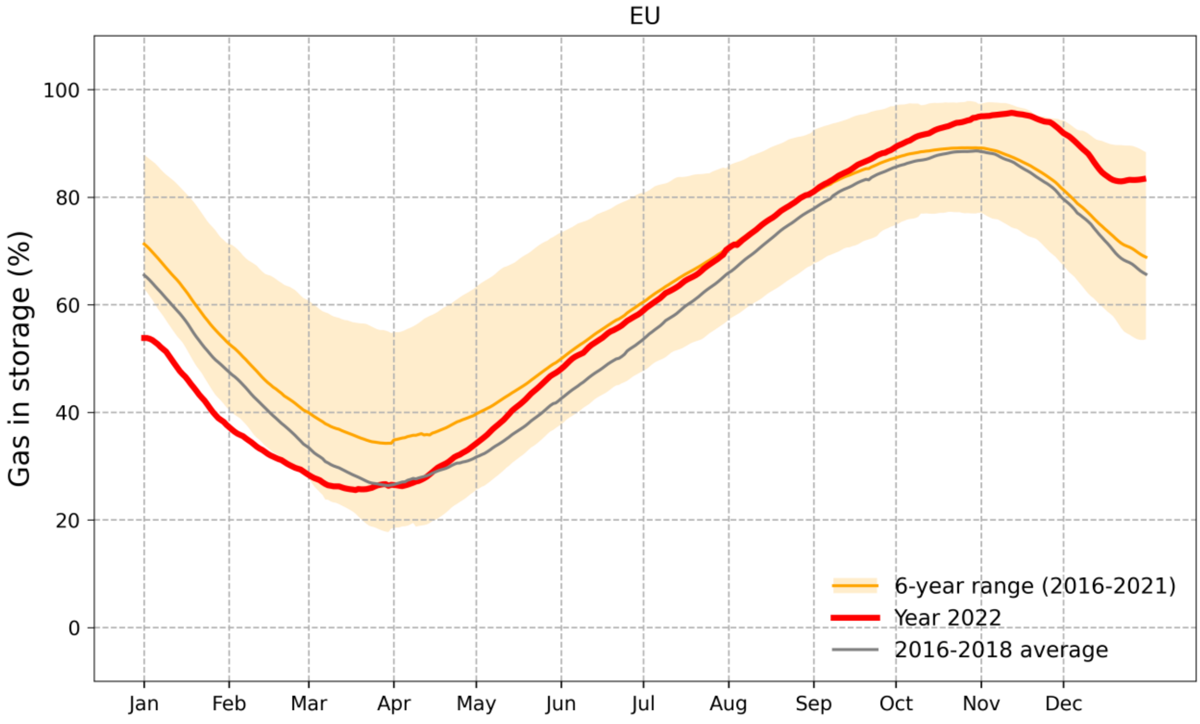


Source: JRC based on AGSI+ Transparency Platform, 2023.

Although the previous figures could be helpful to compare the evolution of the gas in storage in 2022 compared to a single historical year, one could be even more interested in analysing the evolution regarding the average of a set of years. Figure 4 compares the gas storage filling level evolution in the EU in 2022 (red line) with the 6-year average (orange line) and range (orange shadow). Additionally, the average gas storage filling level of the years 2016-2018 is shown in grey. The storage behaviour during years 2016-2018 could be deemed "normal" because the following years were marked by exceptional circumstances which may have led to a different market behaviour, i.e., the potential expiration of a Russia-Ukraine transit agreement at the end of 2019 and the COVID-19 pandemic during 2020-2021. In this figure, we can clearly observe that the gas storage filling level in the first semester of 2022 was well below the average of the last six years (2016-2021), notably during the first quarter of 2022. The filling level was 53.8% on 1 January 2022, i.e., 17.5 percentage points below the 6-year average.

Partly thanks to the mild end of winter 2021-2022, the EU gas in storage level on 1 April 2022 did not fall below 26%, but still remained 8 percentage points below the 6-year average. The gap between the gas filling level in 2022 and the 6-year average shrinks during the first months of the injection season and surpasses the average since mid-September 2022 onwards. The main reasons behind this trend may be related to the legislative proposal on gas storage published on 23 March 2022, which was later on agreed at political level on 19 May 2022, as previously mentioned. Thus, the minimum storage obligations, among other measures, were adopted in the new Gas Storage Regulation (EU) 2022/1032 on 30 June 2022. The EU gas storages were filled up even beyond the 80% target imposed in the new Gas Storage Regulation on 1 November 2022, reaching its maximum on 13 November 2022 (95.7%). The 2022 filling level evolution decreased sharply due to a cold spell at the beginning of December. The decline of gas in storage stopped in mid-December and even increased slightly towards the end of the year. On 31 December 2022, the EU gas storages were filled at 83.4%, quite high compared to the 6-year average (68.9%).

Figure 4. Gas storage filling level in the European Union in 2022 compared with the 6-year average and range (2016-2021) and the average of the reference years 2016-2018.

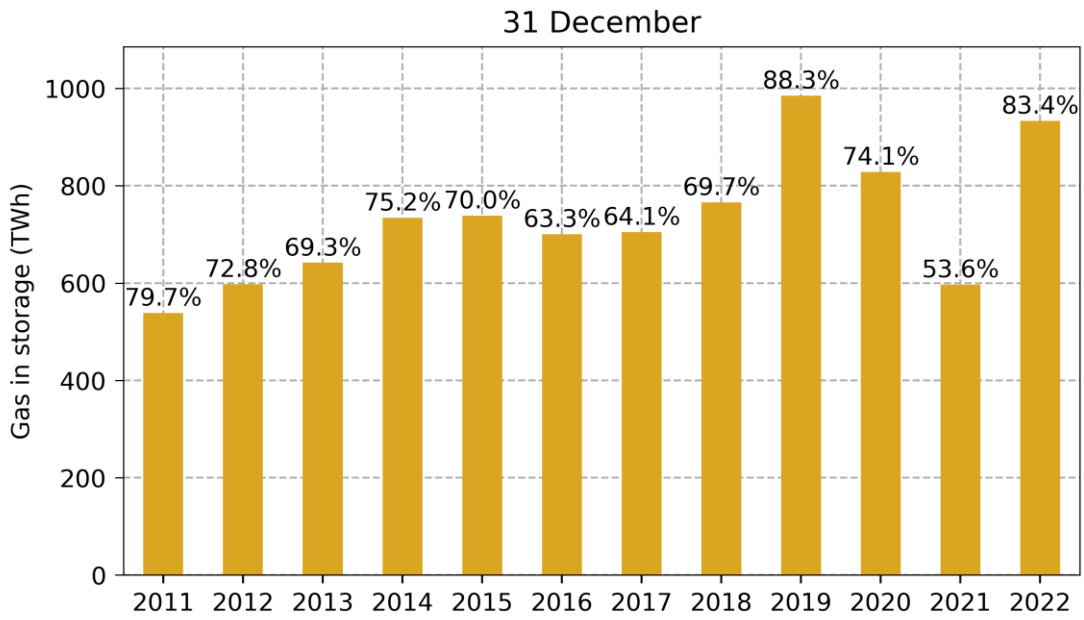


Source: JRC based on AGSI+ Transparency Platform, 2023.

Another useful visualisation is the comparison of stored gas volumes in the EU at a certain point in time. Figure 5, Figure 6, and Figure 7 provide the gas in storage level in TWh, as well as the storage filling level at the top of the bars, on three dates: 31 December representing the end of the calendar year, 1 April and 1 November, respectively. The latter two dates are important because they represent the starting period of the injection season during the gas summer (April-October) and the withdrawal season during the gas winter

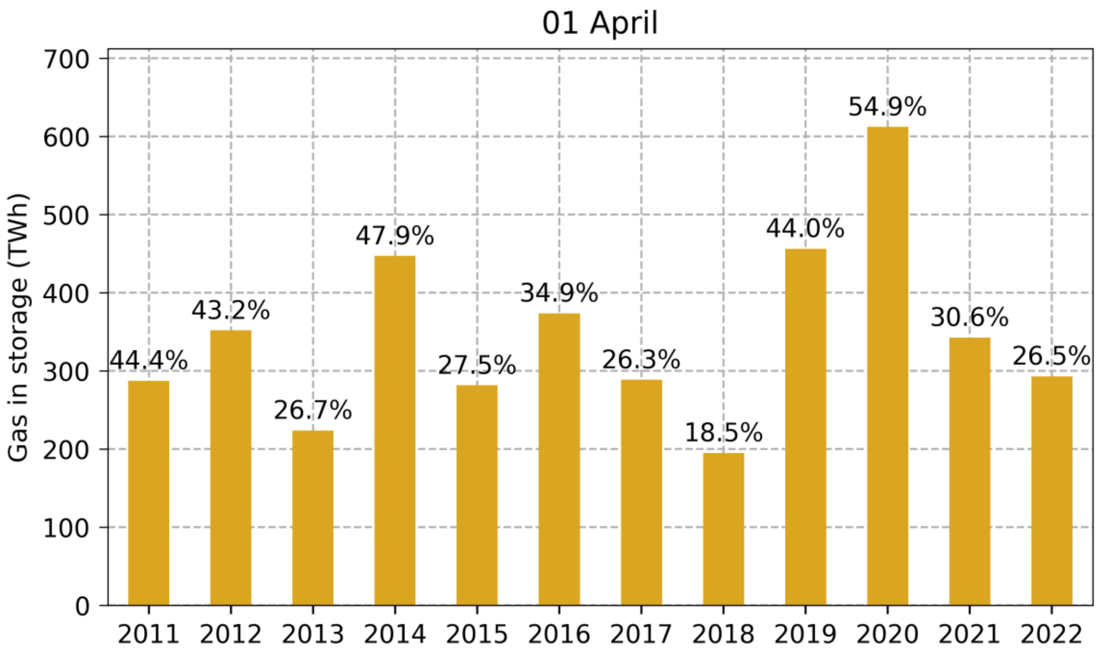
(November-March). Note that we assume an extended gas summer since the injection season could last until the end of October for some storage facilities in the EU. These figures are static snapshots of the previous Figure 2 and Figure 3. We can verify the low filling level of UGSs in the EU at the end of 2021 (53.6%) compared to the previous years, while being similar in absolute values than years 2011-2013. In addition, Figure 7 reinforces the high levels at the beginning of the winter 2022-2023, similar to the ones observed in 2019 and 2020.

Figure 5. Gas in storage level (TWh) in the European Union on 31 December for 12 years (2011-2022). Note that the corresponding filling level is shown on top of each bar.



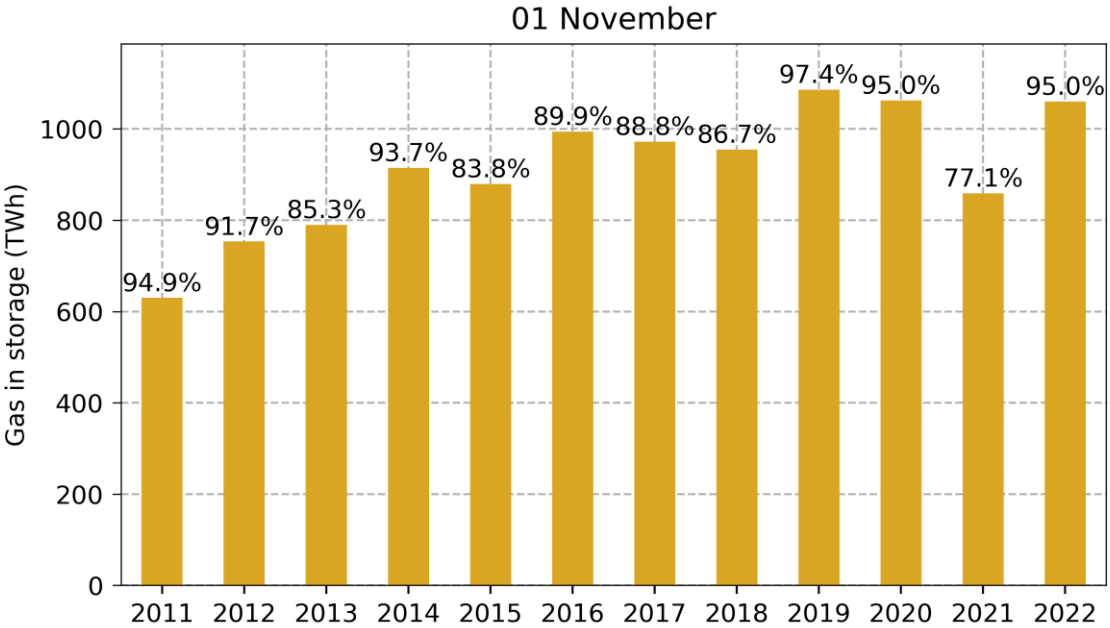
Source: JRC based on AGSI+ Transparency Platform, 2023.

Figure 6. Gas in storage level (TWh) in the European Union on 1 April for 12 years (2011-2022). Note that the corresponding filling level is shown on top of each bar.



Source: JRC based on AGSI+ Transparency Platform, 2023.

Figure 7. Gas in storage level (TWh) in the European Union on 1 November for 12 years (2011-2022). Note that the corresponding filling level is shown on top of each bar.



Source: JRC based on AGSI+ Transparency Platform, 2023.

2.2 Gas storage withdrawal and injection in the European Union

The gas in storage level is obviously determined by the gas injected to or extracted from the storage facility. Figure 8 and Figure 9 provide the EU aggregated gas storage withdrawal and injection, respectively, of the year 2022 (red line) compared with the 6-year average (orange line) and range (orange shadow). For the sake of clarity, the average of the reference years 2016-2018 has been dropped from the figure. Table 1 shows the total gas withdrawn and injected in EU gas storage facilities since 2011, while Table 2 provides the corresponding seasonal values. Note that, in the latter table, gas summer refers to the period spanning from 1 April until 30 September whereas gas winter refers to the period from 1 October until 31 March. The table also shows the net injection during the summer period (i.e., injection minus withdrawal) and the net withdrawal during the winter time (i.e., extraction minus injection).

The EU gas storage withdrawal was moderate in 2022 compared with the average of the last 6 years (see Figure 8), while the EU gas storage injection in 2022 was above the 6-year average most of the days (see Figure 9). As can be seen in Table 1, the annual gas storage injection in 2022 is the highest of the last 12 years, i.e., 994.7 TWh, which is almost 50% higher than the average injection of the last 11 years and 30% higher than the average injection of the last 6 years. In contrast, the total gas withdrawn from storages in 2022 was 653.5 TWh, i.e., 2% lower than the 11-year average and 17% lower than the 6-year average, being larger only than the withdrawal in 2019, a very particular year due to the delayed agreement to continue Russian gas transit across Ukraine.

When looking at the evolution of the gas storage withdrawal and injection during 2022, several observations can be made:

- The gas withdrawn from UGSs in January 2022 was high and similar to the 6-year average. However, gas extractions from EU gas storages towards the end of the winter 2021-2022 are generally lower than the 6-year average (see Figure 8).
- The gas storage withdrawal at the beginning of winter 2022-2023 was relatively low (in November and December 2022) for almost all days. There was a short cold spell during 12-16 December when extractions were above 6 TWh/d.
- There were remarkable high injections at the beginning of 2022 (see Figure 9) in order to save gas for the end of winter 2021-2022 due to the energy crisis started in the second half of 2021. In

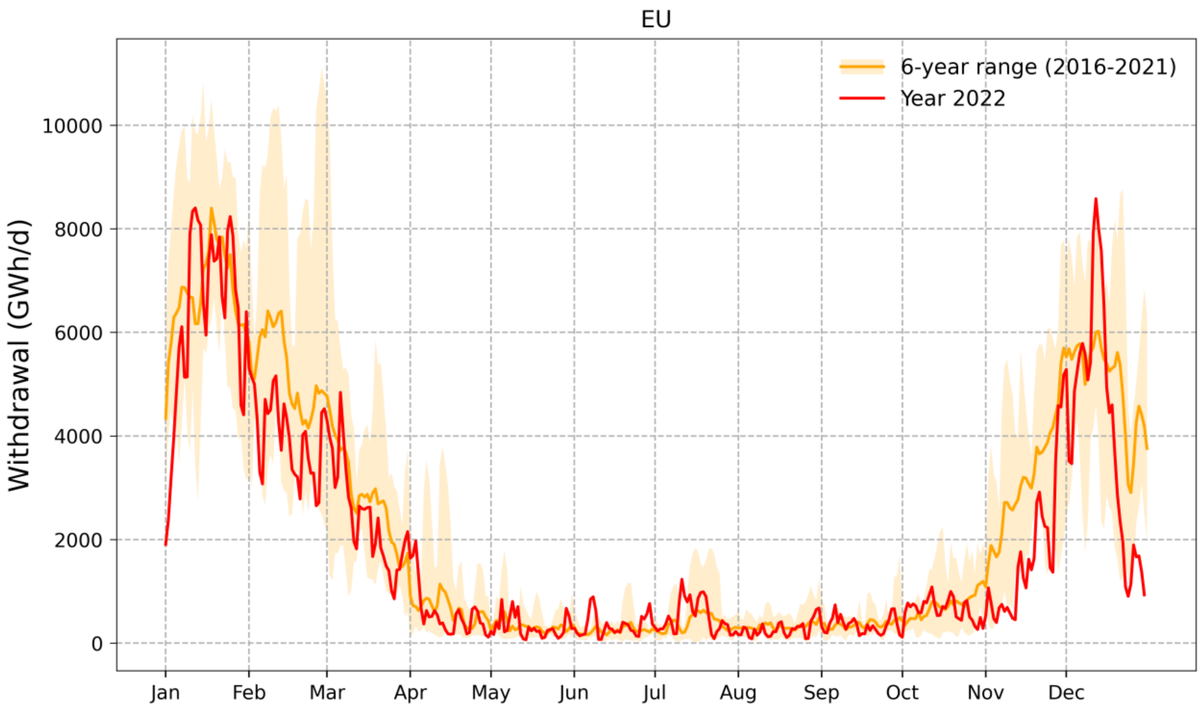
particular, there was a peak of gas injected into EU gas storages of almost 4000 GWh/d on 1 January 2022, almost eight times higher than the 6-year average.

— Injection season in 2022 started earlier than usual. There is a clear peak of gas injected to European Union storages in the last two weeks of March, which are well above the 6-year average.

— There were high injections since mid-April until mid-November 2022 compared to the 6-year average. Even at the end of the year a similar trend is followed by the injections to EU UGS facilities. This is explained by the two regulations that came out during 2022: (i) new Gas Storage Regulation (EU) 2022/1032 setting up minimum storage obligations, although storages were filled up well above the minimum requirement, and (ii) the Regulation (EU) 2022/1369 on coordinated demand-reduction measures for gas in which a voluntary demand reduction of 15% is proposed to save gas for the winter 2022-2023.

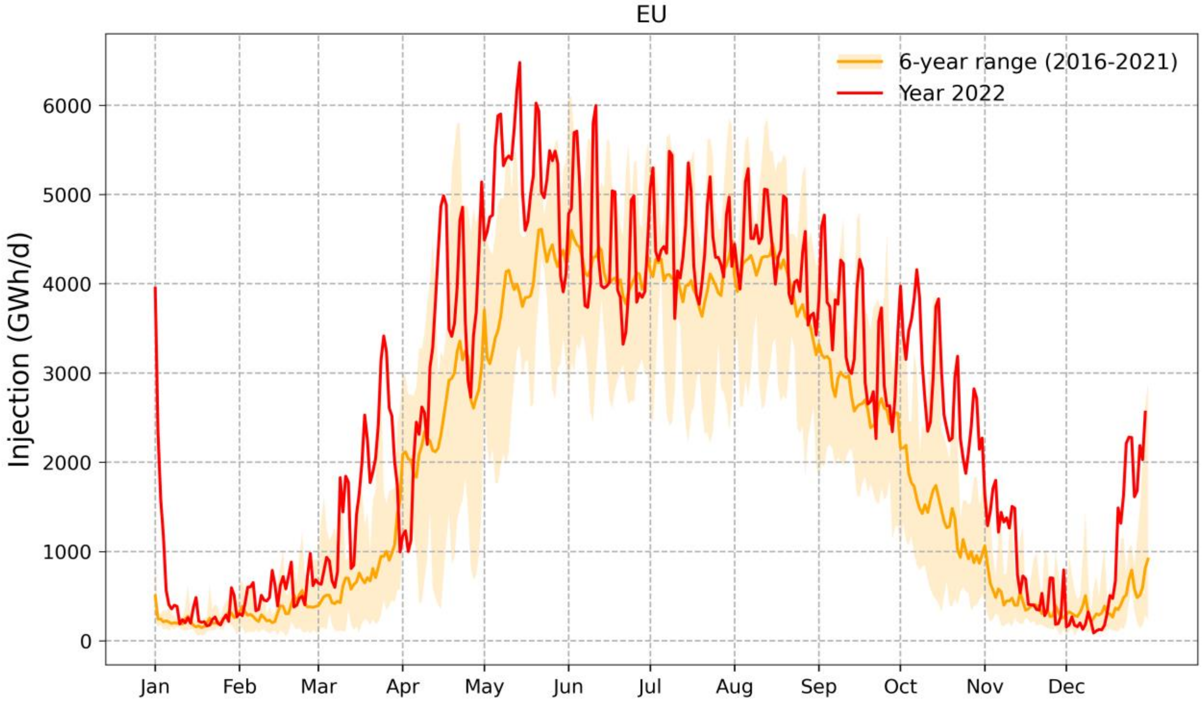
— The weekly seasonality of both withdrawal and injection time series, although more visible in the injection curves (see Figure 8 and specially Figure 9), where the peaks correspond to the weekends, when daily injections typically increase due to the lower gas demand.

Figure 8. Daily gas storage withdrawal in the European Union in 2022 compared to the 6-year average and range (2016-2021).



Source: JRC based on AGSI+ Transparency Platform, 2023.

Figure 9. Daily gas storage injection in the European Union in 2022 compared to the 6-year average and range (2016-2021).



Source: JRC based on AGSI+ Transparency Platform, 2023.

Table 1. Annual injection and withdrawal of underground gas storages aggregated at European Union level.

Year	Annual injection (TWh)	Annual withdrawal (TWh)
2011	400.8	328.7
2012	479.2	460.4
2013	592.4	608.3
2014	565.2	493.8
2015	695.4	723.3
2016	717.4	769.3
2017	811.1	800.3
2018	871.0	809.2
2019	814.7	587.1
2020	650.0	800.8
2021	732.1	968.2
2022	994.7	653.5

Source: JRC based on AGSI+ Transparency Platform, 2023.

During the gas summer 2022 spanning from 1 April until 30 September, natural gas injected to the EU gas storage facilities amounts to 765.4 TWh while 73.5 TWh was extracted from storages during this period, thus leading to 691.9 TWh of net injection during gas summer 2022. This represents a 33% increase with respect to the average net gas injected to EU storages in the last 11 years and an 18% increase with respect to the 6-year average.

The net withdrawal during winter 2021-2022 was quite moderate compared to the last 6 years. It reached 541.0 TWh, just 8.5% lower than the 6-year average, but 8.5% higher than the 11-year average given the low gas extracted from storages before 2016.

Table 2. Total injection and withdrawal (TWh) of underground gas storages aggregated at European Union level during gas summer and winter periods.

Summer	Injection	Withdrawal	Net injection	Winter	Injection	Withdrawal	Net withdrawal
2011	357.5	19.9	337.6	2011	20.4	188.5	168.1
2012	416.4	36.6	379.7	2011-2012	47.2	364.2	317.1
2013	513.3	45.2	468.1	2012-2013	49.7	566.7	517.0
2014	477.3	43.4	434.0	2013-2014	99.0	412.1	313.2
2015	608.9	43.1	565.8	2014-2015	74.3	696.7	622.4
2016	649.5	49.4	600.1	2015-2016	88.4	580.6	492.2
2017	693.9	50.3	643.6	2016-2017	89.8	793.9	704.1
2018	753.8	48.2	705.5	2017-2018	101.9	823.7	721.8
2019	682.1	69.2	612.9	2018-2019	158.3	595.1	436.8
2020	556.9	95.0	462.0	2019-2020	103.0	568.2	465.1
2021	602.5	106.4	496.2	2020-2021	99.4	827.4	728.1
2022	765.4	73.5	691.9	2021-2022	169.8	710.8	541.0

Source: JRC based on AGSI+ Transparency Platform, 2023.

2.3 Underground gas storage level by country

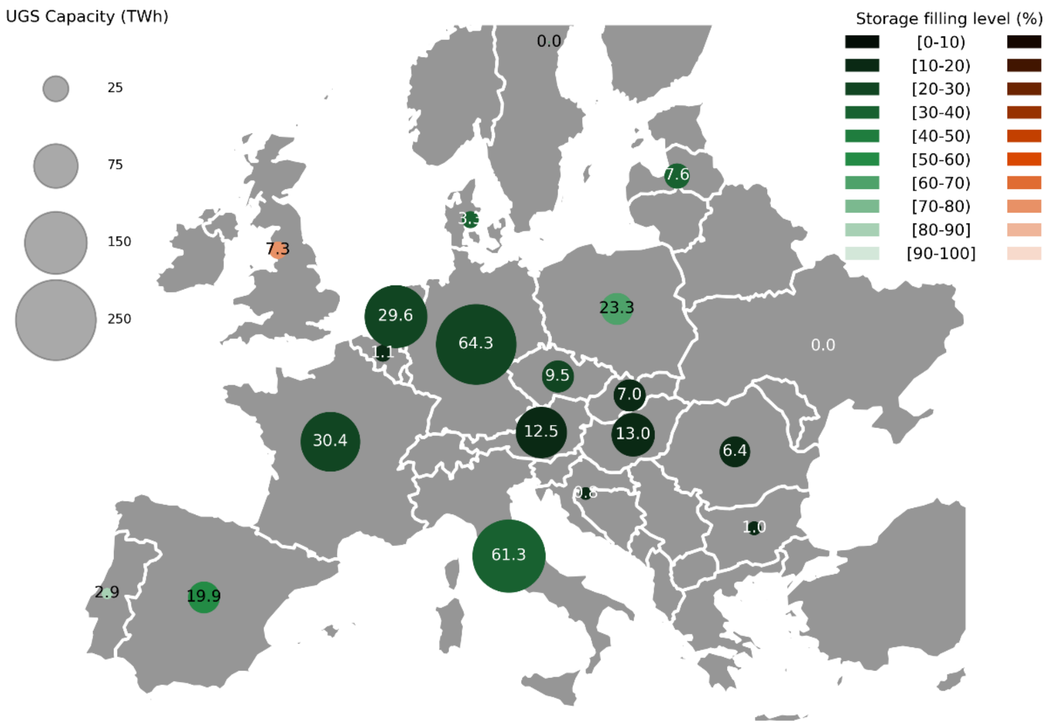
Figure 10, Figure 11, and Figure 12 show the situation of the European underground gas storages aggregated at country level for three days in 2022: 1 April, 1 November and 31 December. These days have been chosen because they represent the first day of the so-called gas summer (or injection season), the first day of the gas winter ([19]) (or withdrawal season), and the last day of the calendar year. The figures include gas in storage level in TWh (numbers inside circles), storage filling level in relative terms (colour gradient code), and the working gas volume (area of each circle) declared that day in the AGSI+ Transparency Platform. Storage filling level is indicated in a green gradient colour scheme for UGSs in EU Member States and in an orange gradient colour scheme for UGSs in United Kingdom and Ukraine.

These figures allow for a qualitative assessment of the storage filling level across European countries and help identify countries that are lagging behind when injecting gas during summer or countries delivering gas at a higher pace during winter. In Figure 10, we can observe the low levels of gas in storage reached on 1 April 2022 by country except for Ukraine in which aggregated storage data are provided in the Transparency Platform from 16 April 2022 onwards. Poland and Portugal have their storages filled at least above 50% at the beginning of the injection season. The Portuguese gas reserves are used to balance not only seasonal but also daily fluctuations of supply and demand, which explains the high levels around that date.

At the beginning of the withdrawal season (1 November 2022), Latvian storage has a lower relative filling level than the rest of the EU countries (see Figure 11). It should be noted that the Inčukalns UGS in Latvia has a high storage capacity compared to the Latvian average gas consumption. At the end of the year 2022, storage filling level is unevenly distributed across EU countries and the relative gas in storage level in Latvia is still the lowest of the EU (see Figure 12).

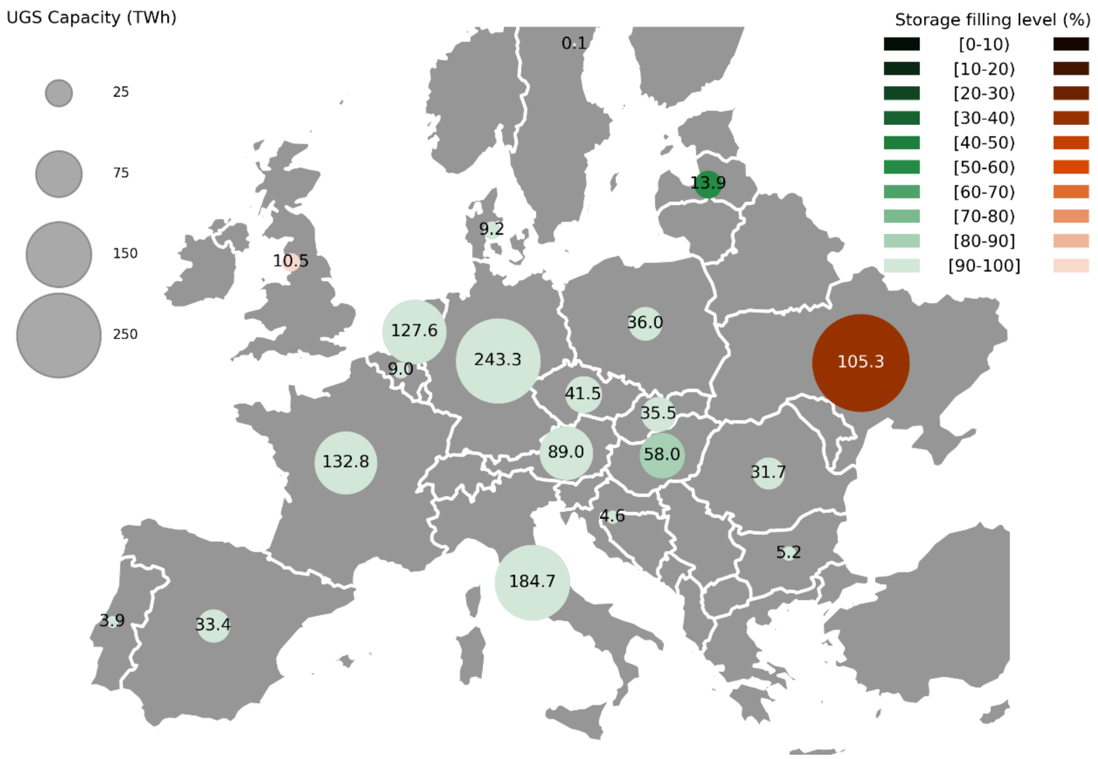
([19]) Typically, the gas winter spans from 1 October of one year until 31 March of the following year. However, the underground gas storages in the European Union used to refill storages until 1 November. For this reason, this day has been selected as the beginning of the withdrawal season.

Figure 10. Gas in storage level (TWh) and capacity (TWh) as well as storage filling level (%) on 1 April 2022 by country including EU Member States (in green) and non-EU countries (in orange).



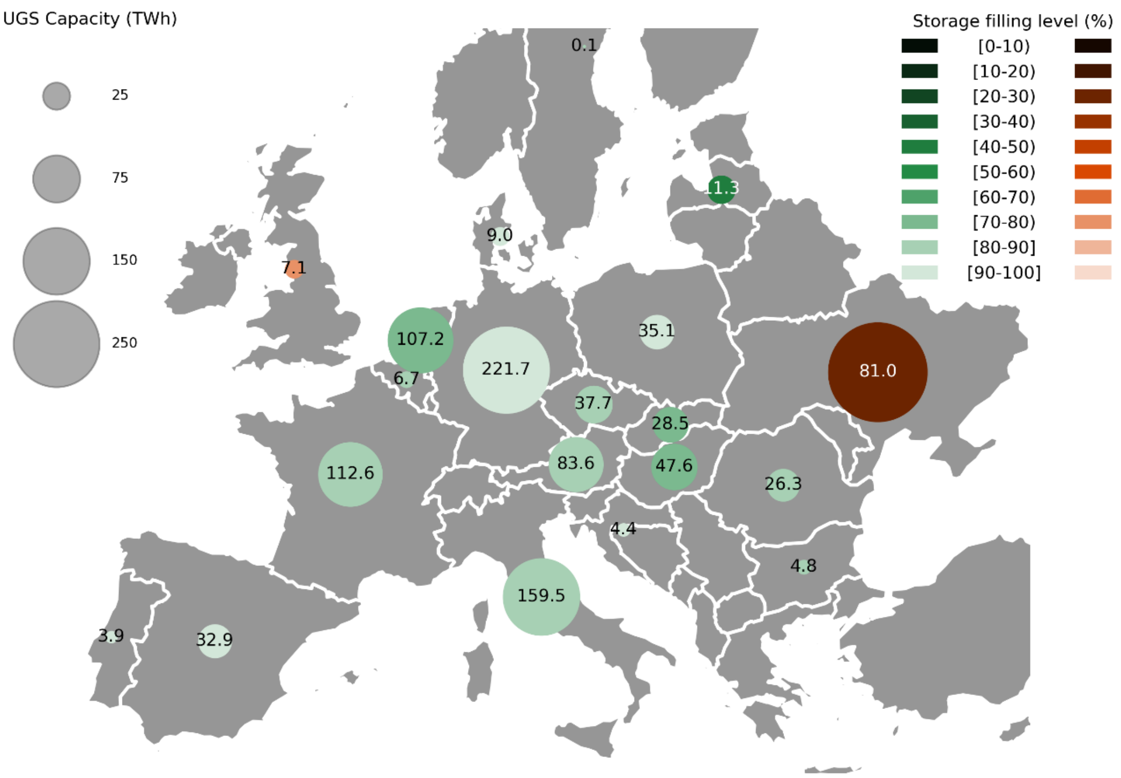
Source: JRC based on AGSI+ Transparency Platform, 2023.

Figure 11. Gas in storage level (TWh) and capacity (TWh) as well as storage filling level (%) on 1 November 2022 by country including EU Member States (in green) and non-EU countries (in orange).



Source: JRC based on AGSI+ Transparency Platform, 2023.

Figure 12. Gas in storage level (TWh) and capacity (TWh) as well as storage filling level (%) on 31 December 2022 by country including EU Member States (in green) and non-EU countries (in orange).



Source: JRC based on AGSI+ Transparency Platform, 2023.

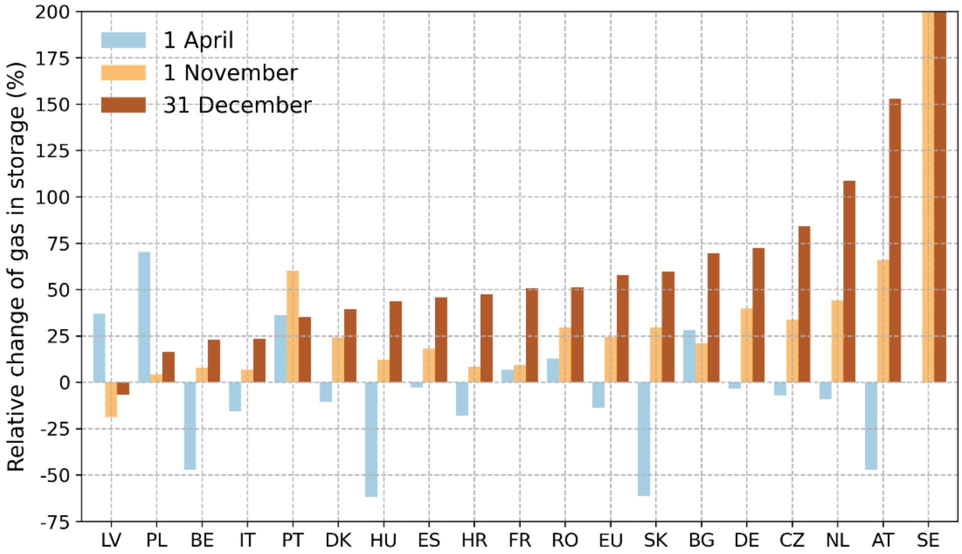
Figure 13 shows the relative change of gas in storage in 2022 compared to the one in 2021 for the previous three key days and for all countries with UGS facilities. Changes at EU level are also reported in the bar plot. Numerical values are provided in tabular form in Annex 1.

On 1 April 2022, the gas stored at EU level was 15% lower than in 2021 (293 TWh versus 343 TWh). This reduction is partly caused by the low levels observed in the storages of Austria, Belgium, Hungary, and Slovakia, wherein the gas stored in 2022 decreased by more than 40% compared to 2021 levels. Smaller reductions can be noticed in Croatia, Czechia, Germany, Italy, the Netherlands, Denmark, and Spain. In contrast, Bulgaria, France, Latvia, Poland, Portugal, and Romania reached the beginning of the injection season with higher storage levels than in 2021.

From 1 April 2022 until the beginning of the heating season (1 November 2022), there were high record net injection levels, as explained previously, thanks mainly to the energy policies adopted in the European Union during 2022. As a consequence, the EU storages were filled up to 1060 TWh on 1 November 2022, which represents an increase of 23% compared to 2021. The successful results of the policies are reflected in Figure 13, in which all countries except Latvia present higher storage levels in 2022 compared to 2021 in order to face the winter 2022-2023. Although the gas stored in Latvia is 3.2 TWh lower than in 2021, it complies with the Gas Storage Regulation.

On 31 December, the gap between the gas stored in 2022 compared to the one in 2021 has increased dramatically, being the EU storage level equal to 933 TWh (i.e., 56% higher than at the end of 2021). When looking at the regional differences, one can observe a similar trend for all countries except for Latvia with positive relative changes over 15%. Even in Latvia, the relative change on 31 December has decreased to 6.6% compared to the relative change two months earlier.

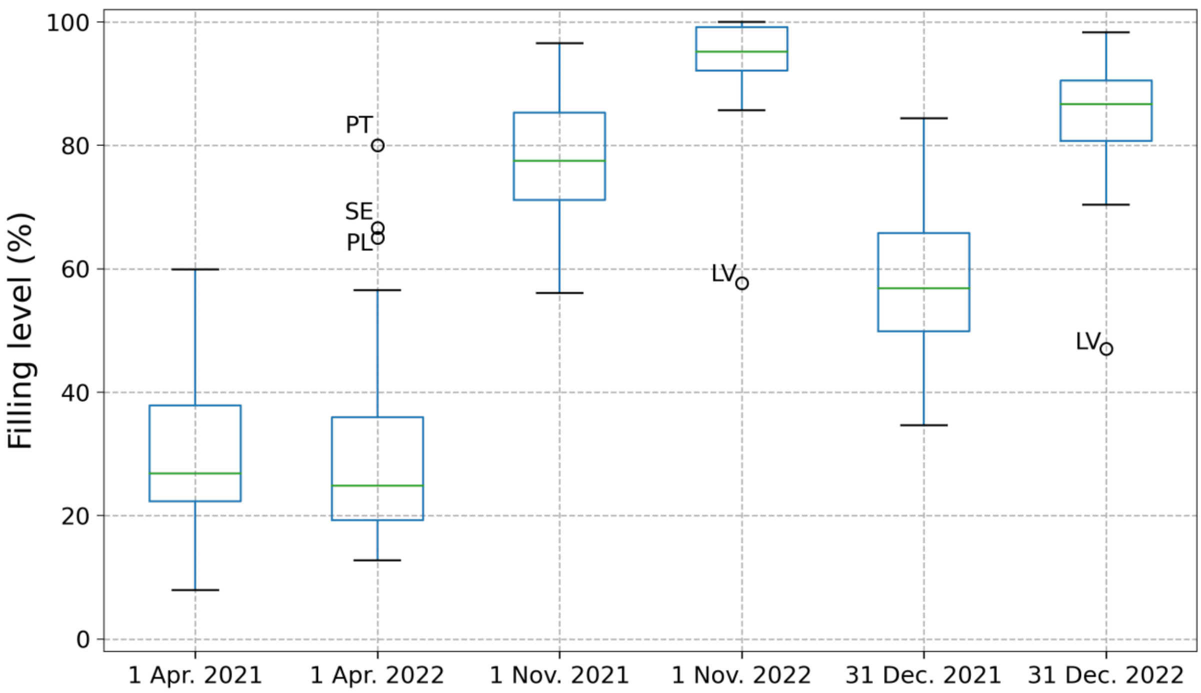
Figure 13. Relative change of gas in storage in 2022 with respect to 2021 on three key days (1 April, 1 November and 1 December) at country and EU level.



Source: JRC based on AGSI+ Transparency Platform, 2023.

Finally, the dispersion of the relative filling levels across EU countries is analysed in Figure 14 for the previous three days in years 2021 and 2022. The first general remark is that the dispersion of the filling level across Member States is visibly lower in 2022 compared to 2021, especially on 1 November. The main reason of the low dispersion at the beginning of the winter 2021-2022 relies on the minimum storage obligations imposed by the Gas Storage Regulation. The second remark is that the change of the median filling level in the EU has increased along the time, being -2% on 1 April, 18% on 1 November, and 30% on 31 December.

Figure 14. Boxplot of the country-specific storage filling levels on three key days (1 April, 1 November and 1 December) and years 2021-2022.



Source: JRC based on AGSI+ Transparency Platform, 2023.

2.4 Impact of formerly owned/operated Gazprom storage sites

Russian state-owned Gazprom had long term booked capacity, operated or owned before 2022, with eight gas storage facilities in some countries of the European Union such as Germany, the Netherlands, Austria, and Czechia. Table 3 lists the formerly Gazprom storage sites. Some of these storages were partially owned or operated by Gazprom, e.g., Dambořice, Bergermeer, Katharina, and Etzel EKB. UGS Katharina ([20]) was a joint venture between VNG Gaspeicher GmbH (50%) and Gazprom Export (50%). Etzel EKB was a joint venture between BP, Ørsted, and Gazprom Germania ([21]), in which Gazprom Germania seemed to hold 33% of the shares (Sharples, 2021). The EU storage capacity owned or operated by Gazprom in 2021 was around 10% of the EU storage capacity, i.e., 112 TWh.

In summer 2022, Member States with Gazprom storage sites took measures to protect their energy security based on the new Gas Storage Regulation. For instance, Gazprom sites in Germany were nationalised, an Austrian site was given to another operator under new “use it or lose it” rules, and similar rules applied in Czechia and the Netherlands.

It should be emphasised that, in August 2022, the AGSI+ Transparency Platform carried out some changes regarding the UGS Haidach ([22]). Before that date, UGS Haidach (GSA) reported a working gas volume of 21.3 TWh. After August 2022, RAG Energy Storage marketed 14.1 TWh of working gas volume of UGS Haidach (GSA) ([23]) while UGS Haidach (astora) took over the remaining 7.3 TWh of UGS Haidach (GSA).

Table 3. Underground gas storages owned or operated (fully or partially) by Gazprom in 2021.

Country	UGS fully or partially owned by Gazprom
Czechia	UGS Dambořice* (50%)
The Netherlands	UGS Bergermeer (40% reserved for Gazprom use)
Germany	UGS Jemgum H (astora) UGS Rehden (astora) UGS Katharina (50% Gazprom) Etzel EKB (33% Gazprom)
Austria	UGS Haidach (astora) UGS Haidach (GSA)

Figure 15 depicts the evolution of the gas filling level of the storage sites owned/operated by Gazprom (orange dashed line) and the rest of European sites (blue dashed line). The black line shows the gas filling level of all EU sites together. Until 2021, there was a similar behaviour between Gazprom (GP) and non-GP storages, being the GP storages filled slightly earlier and even higher than the non-GP ones. Particularly years 2019 and 2020 were characterised by an unusual management of storages due to two reasons: (i) the end of the transit contract between Russia and Ukraine at the end of 2019, and (ii) the mild winter 2019-2020 which prevented storages from being depleted.

In 2021, a declining trend of Gazprom-related storages is quite visible compared to non-GP ones, thus reaching a minimum filling level of 16.5% on 1 April 2021 for the GP storage sites compared to 32.2% for the rest of the storages. During the injection season in 2021, Gazprom-related EU storages kept gas injection to a minimum, not reaching even a filling level of 30% at the beginning of the winter 2021-2022. It is true that the rest of storages were not refilled at the same rate as previous years, but still reached a collective filling level above 80%.

Policy-driven decisions - mainly the new Gas Storage Regulation - led to the refilling of former Gazprom storage sites since the second quarter of 2022, which is reflected in Figure 15 by the steep increase in GP-related storages during the last year. The filling level patterns of GP- and non-GP-related storages were again similar at the end of 2022.

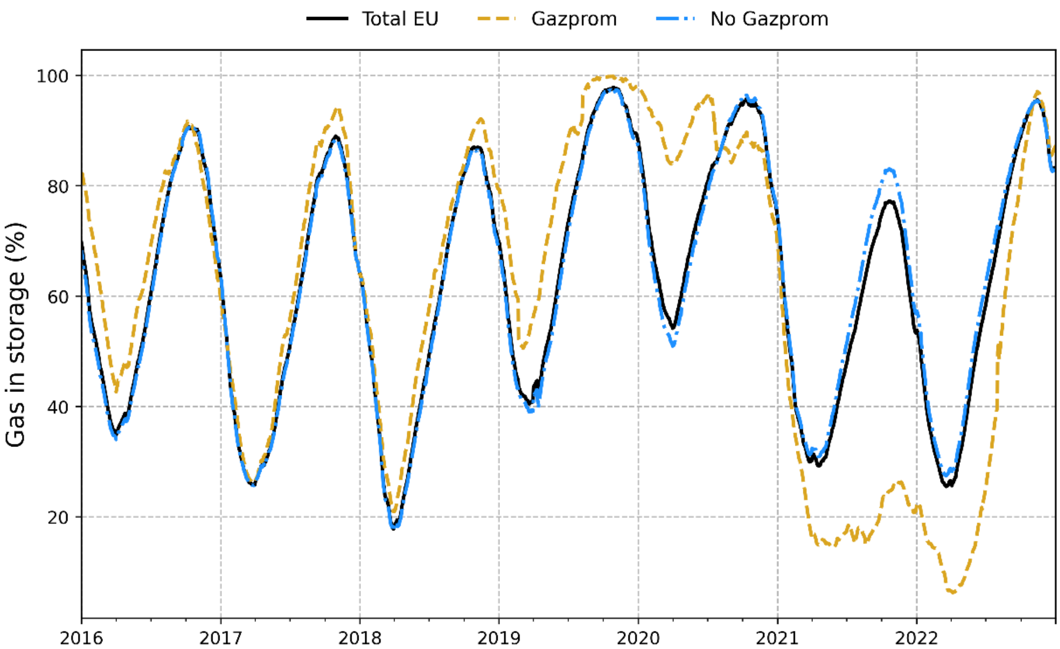
([20]) https://www.ugs-katharina.de/en/home.
https://www.ugs-katharina.de/de/veroeffentlichungen/publikationen?file=files/content/publikationen/2022-12/Statement%20der%20Erdgasspeicher%20Peissen%20GmbH%20zu%20den%20Pressemeldungen%20vom%2003.10.2022.pdf

([21]) https://www.ze.com/datavendor/ekb-storage/.
https://ekb-storage.de/en/the-ekb/company/.

([22]) https://agsi.gie.eu/news.

([23]) https://www.rag-energy-storage.at/en/.

Figure 15. Evolution of the gas filling level of the owned/operated Gazprom storage sites (orange) in Europe and the non-Gazprom sites (blue).



Source: JRC based on AGSI+ Transparency Platform, 2023.

Table 4 and Table 5 provide a detailed summary of the Gazprom-related filling levels on 1 November 2021 and 2022 in the European Union per facility and Member State, respectively. The filling levels of Gazprom-related sites at the beginning of the winter pre- and post-Regulation change dramatically, being 26% on 1 November 2021 and 94% in the same date in 2022 (see Table 5). The highest Gazprom storage capacity in the EU can be identified in the German storage Rehden (Astora) with 43.7 TWh, followed by the Austrian UGS Haidach (GSA) with 21.3 TWh. Both of them were drained on 1 November 2021, not even reaching 10% of their corresponding capacities, i.e., 9.5% in Rehden (Astora) and 2.0% in Haidach (GSA). In 2022, UGS Rehden (Astora) was filled 83 percentage points more than in 2021 on the same day. The filling level increase in the Austrian UGS Haidach (GSA) in 2022 is difficult to quantify since its ownership was split between other two Austrian sites, namely Haidach (Astora) and Haidach (RAG), although both of them reached filling levels above 85% of their respective capacities.

Table 4. Storage facilities owned/operated by Gazprom in 2021 and filling level in November 2021 and 2022.

Facility (Operator)	Country	Storage capacity operated by Gazprom 2021 (TWh)	Filling level 1 Nov 2021	Storage capacity in 2022 (TWh)	Filling level 1 Nov 2022
Haidach (Astora)	AT	11.0	56.3%	18.6	94.3%
Haidach (GSA)	AT	21.3	2.0%	-	-
Haidach (RAG)	AT	-	-	14.0	86.9%
Dambořice (Moravia Gas Storage)	CZ	2.2	44.6%	2.2	85.0%
Jemgum (Astora)	DE	8.2	86.8%	8.2	99.9%
Rehden (Astora)	DE	43.7	9.5%	43.7	92.5%
Etzel EKB (EKB)	DE	3.5	93.5%	3.5	100.0%
Katharina (Erdgasspeicher Peissen)	DE	2.8	43.3%	3.0	98.0%
Bergermeer (TAQA Gas Storage)	NL	19.3	30.1%	18.3	98.6%
	TOTAL	112.0	26.1%	111.6	93.9%

Source: JRC based on AGSI+ Transparency Platform, 2023.

Half of the Gazprom-related storage capacity was allocated in Germany, while the other half was split essentially between Austria and the Netherlands (see Table 5). Gazprom sites in Czechia represented only 2% of its total capacity in the EU. At country level, the lowest filling level on 1 November 2021 was observed in Austria (20%) followed by Germany (27%), which were the largest Gazprom-related storage sites in the EU. After the adoption and implementation of the new Gas Storage Regulation, storage filling levels increased by 71 and 67 percentage points on the same day one year later.

Table 5. Storage capacity owned/operated by Gazprom in 2021 by country and filling level on 1 November 2021 and 2022.

Country	Gazprom owned/operated capacity 2021 (TWh)	Filling level 1 Nov. 2021	Filling level 1 Nov. 2022
Austria	32.3	20%	91%
Czechia	2.2	45%	85%
Germany	58.2	27%	94%
The Netherlands	19.3	30%	99%
TOTAL	112.0	26%	94%

Source: JRC based on AGSI+ Transparency Platform, 2023.

3 Liquefied natural gas

Gas Infrastructure Europe (GIE) also provides data for the Liquefied Natural Gas (LNG) terminals in Europe by means of its ALSI Transparency Platform ([24]). Its structure is similar to the one for gas storages, namely the AGSI+ Transparency Platform. ALSI covers European Union countries with LNG facilities and the United Kingdom, although the latter no longer provides data.

Currently, there are 11 EU countries providing information to the platform on a daily basis, namely Belgium, Croatia, France, Greece, Italy, Lithuania, the Netherlands, Poland, Portugal, Spain, and, since 2023, Germany. As mentioned previously, the United Kingdom does no longer participate in the LNG data sharing since Brexit was realised, but pre-Brexit information still can be found in the platform.

We download the required LNG data on a daily or weekly basis through the offered API service by using the python requests module ([25]). The API provides quick, continuous, and direct access to the database and allows to filter, create queries and export the data as required. It is also important to download the data frequently because corrections are periodically implemented. Data is then processed in Python 3.7 with a Jupyter notebook ([26]) and the corresponding visualization and data management libraries.

The data provided in the Transparency Platform for each individual LNG terminal, company or country are as follows:

— LNG inventory: Aggregated amount of LNG in the LNG tanks in $10^3 \cdot m^3$ LNG.

— Send-out flow: Aggregated gas flow out of the LNG facility in GWh/d.

— Declared Total Maximum Inventory (DTMI) in $10^3 \cdot m^3$ LNG.

— Declared Total Reference Send-out (DTRS) in GWh/d.

— Data quality status, which can be estimated, confirmed, or no data.

As similarly done in AGSI+ TP, GIE is progressively updating its LNG Transparency Platform following Council Regulation (EU) 2022/2576 and inputs as received from LNG System Operators (LSOs). Hence, the LSOs provide the regasification capacity forecast by LNG terminal in ALSI TP ([27]). Planned usage data is made available for six months ahead, while the information and status updates are updated every month.

3.1 Inventory and send-out flow of liquefied natural gas in the European Union

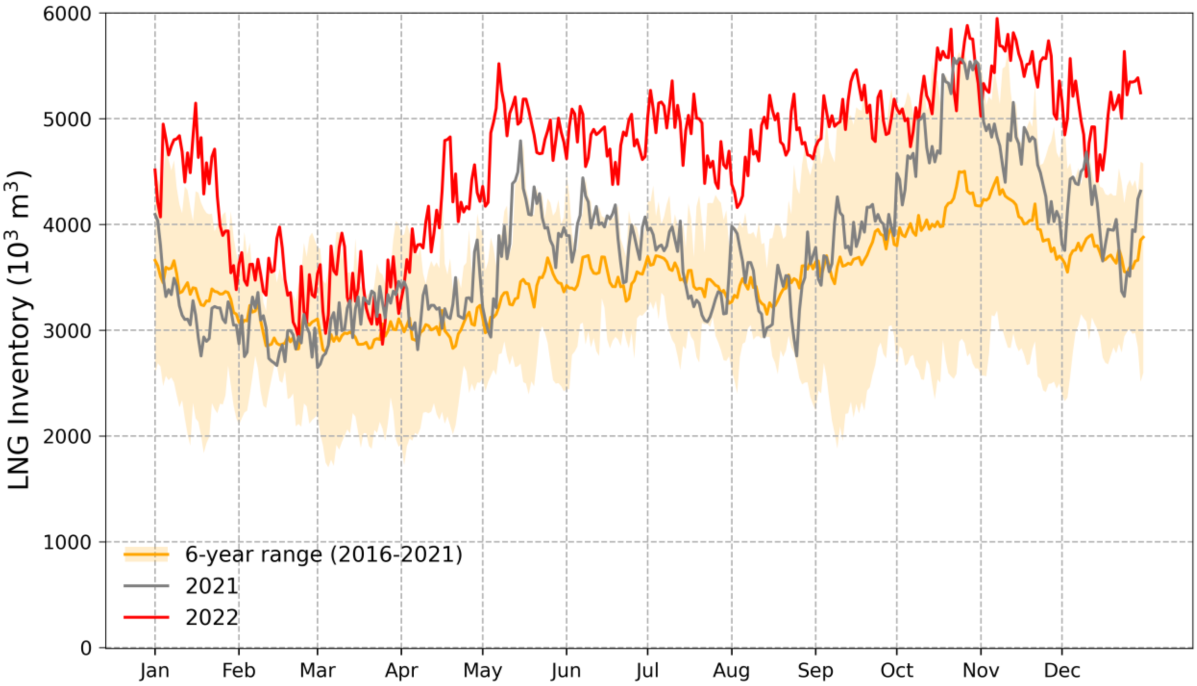
The current LNG send-out capacity is 6113.5 GWh/d ([28]) in the European Union whereas the capacity of the LNG tanks is almost 8000 $10^3 \cdot m^3$ LNG. Figure 16 and Figure 17 illustrate, respectively, the daily LNG stock levels and send-out flows within the European Union. The red line represents the trends in 2022, while the grey line represents the trends in 2021. Meanwhile, the orange line and shadow depict the 6-year average and range from 2016 to 2021. These visuals serve as valuable tools to observe the functionality of the aggregated LNG terminals in the EU.

Notably, the LNG inventory has maintained historically high levels for the majority of 2022, with a particular emphasis on the period since April 2022. The EU LNG storage levels averaged $4631 \cdot 10^3$ m^3 LNG in 2022, a 24% increase compared to the 2021 average of $3747 \cdot 10^3$ m^3 LNG and a 33% increase compared to the 2016-2021 average of $3477 \cdot 10^3$ m^3 LNG.

The EU LNG send-out flows are significantly exceeding their daily historical maximum levels. In 2022, the annual LNG flow experienced a significant surge, reaching 1315.3 TWh, which is 73% higher than in 2021 (760.8 TWh), and double the average of the past 6 years, which was 636.7 TWh.

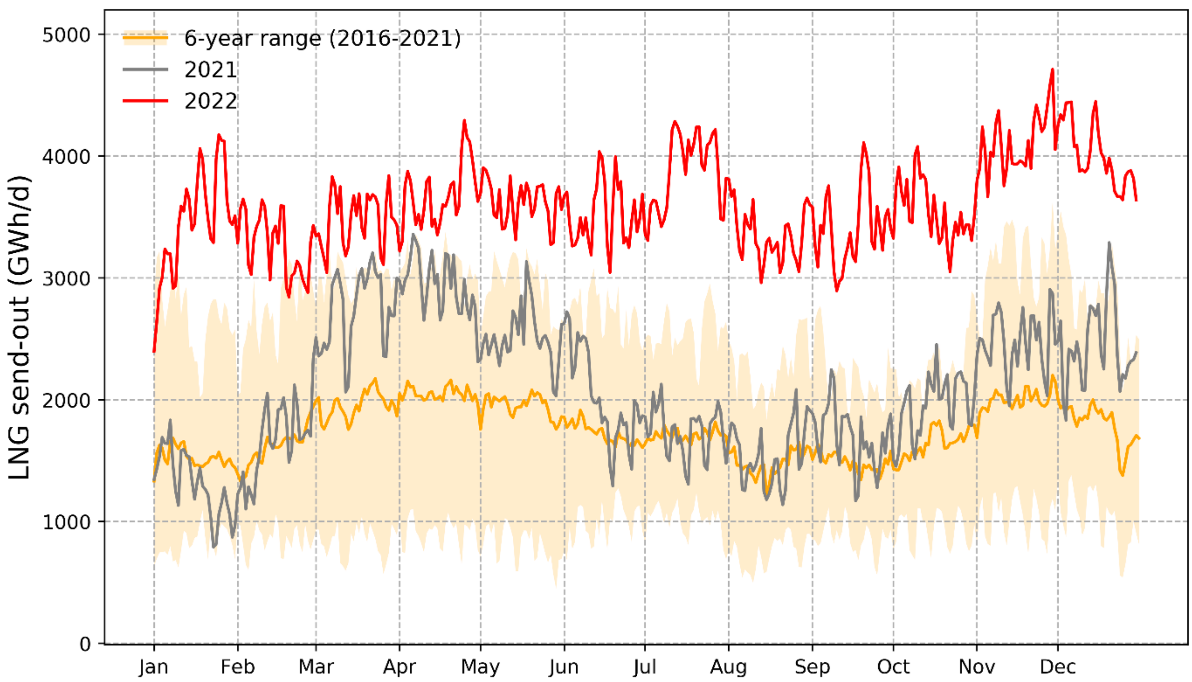
([24]) https://alsi.gie.eu/.
([25]) https://docs.python-requests.org/en/latest/.
([26]) https://jupyter-notebook.readthedocs.io/en/stable/notebook.html.
([27]) https://alsi.gie.eu/capacity-forecast.
([28]) Capacity indicated in the ALSI Transparency Platform on 31 December 2022.

Figure 16. European Union LNG inventory in 2022, 2021, and 6-year average and range (2016-2021).



Source: JRC based on ALSI Transparency Platform, 2023.

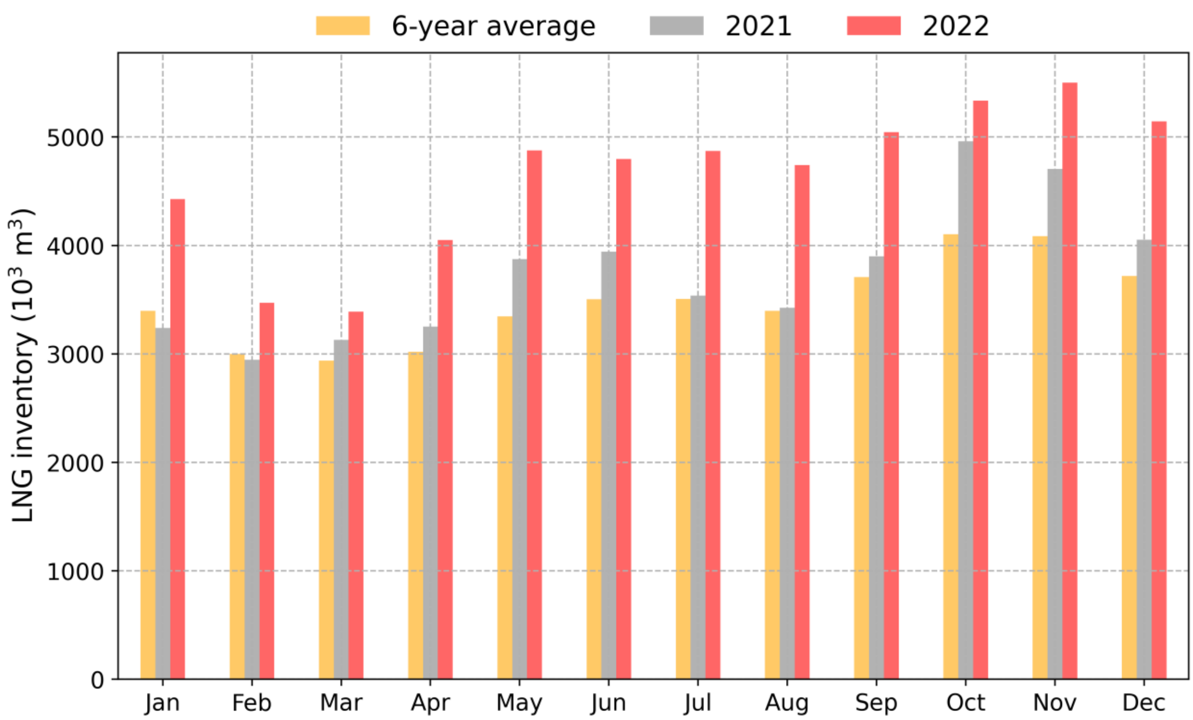
Figure 17. European Union LNG send-out flow in 2022, 2021, and 6-year average and range (2016-2021).



Source: JRC based on ALSI Transparency Platform, 2023.

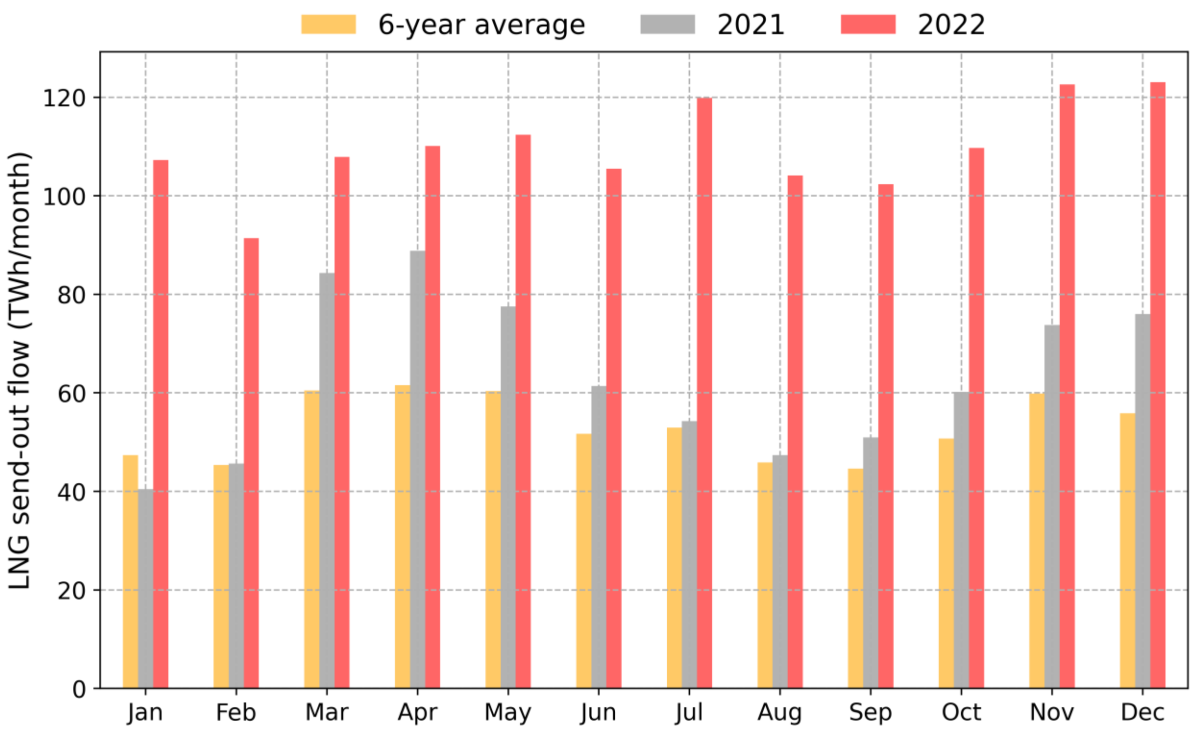
The monthly evolution of the LNG inventory and send-out flow at EU level is represented in Figure 18 and Figure 19, respectively. Note that the tabular content of these figures is provided in Annex 2. Both plots show the 2016-2021 average, 2021, and 2022 values in orange, grey, and red bars, in that order. There is an increasing pattern of LNG stocks since the second quarter of 2021, reaching average values above $4500 \cdot 10^3$ m^3 LNG from May 2022 onwards. In 2021, there are positive changes with respect to the 6-year average (2016-2021) in 10 months that varying between 1% and 21%. In 2022, the average LNG stored in the tanks is kept always above historical monthly figures, i.e., there are slight increases of 8% in March and October 2022 compared to the 2021 values, and significant surges of 17-38% for the remaining months.

Figure 18. Average LNG inventory per month in the European Union in 2022, 2021, and 6-year average (2016-2021).



Source: JRC based on ALSI Transparency Platform, 2023.

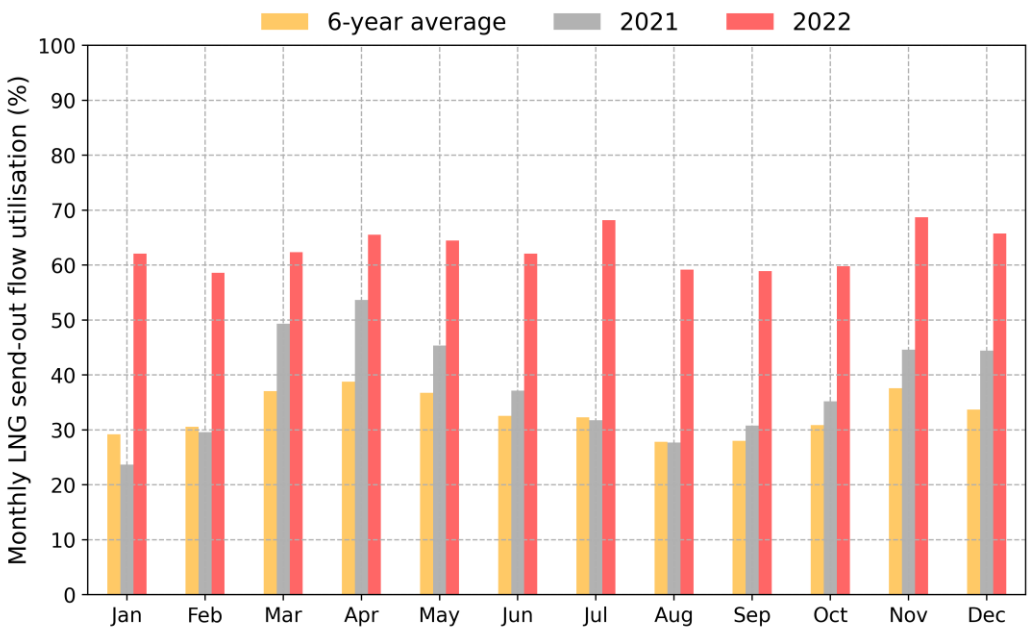
Figure 19. Monthly LNG send-out flow in the European Union in 2022, 2021, and 6-year average (2016-2021).



Source: JRC based on ALSI Transparency Platform, 2023.

Figure 20 displays the monthly utilisation of LNG send-out flow in the European Union, which is determined by dividing the monthly LNG send-out flow by the corresponding LNG send-out capacity. The monthly pattern mirrors that of the EU LNG send-out flow. Analysis of the 6-year average utilisation reveals that LNG terminals were not fully utilised, with utilisation levels staying below 40% throughout the year. In 2021, there was an uptick in LNG flows during March, April, and May, resulting in a utilisation rate of 45-53%, and again during the final months of the year when gas prices rose sharply, leading to utilisation rates of approximately 45%. In 2022, the EU natural gas system experienced a significant shift in paradigm, with LNG send-out flows increasing dramatically and utilisation rates reaching nearly 60% every month. The annual LNG utilisation in the EU rose to 63%, representing a 25-percentage point increase over the previous year's utilisation rate (38%) and almost double the EU's 6-year average utilisation rate (32.9%).

Figure 20. Monthly LNG send-out utilisation in the European Union in 2022, 2021, and 6-year average (2016-2021).



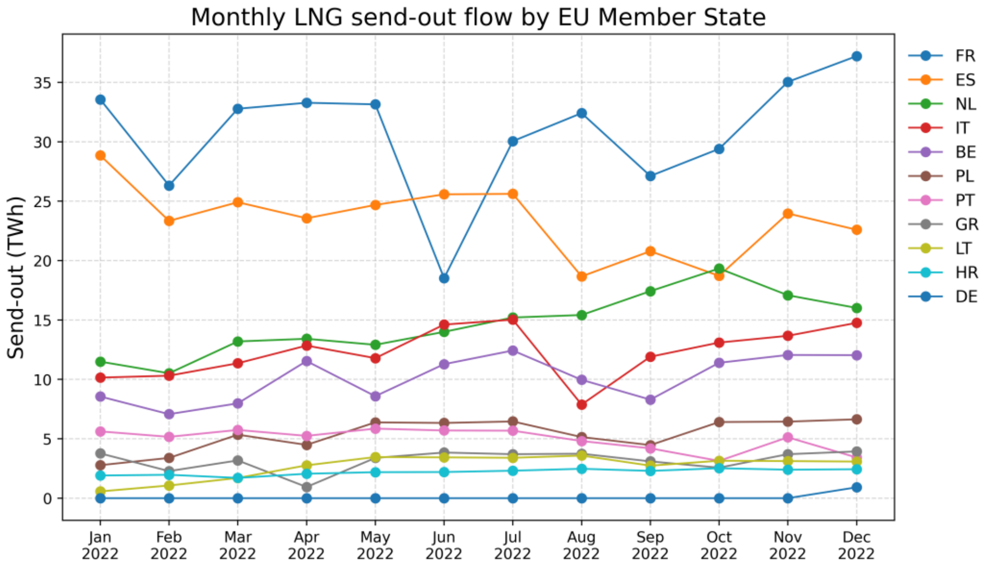
Source: JRC based on ALSI Transparency Platform, 2023.

3.2 Regional distribution of liquefied natural gas

The countries with the largest LNG regasification capacities in the EU are Spain, France, the Netherlands, and Italy, which together account for 74% of the total EU regasification capacity. Spain has the highest capacity with 1910.4 GWh/d (31% of the total) and the largest volume of LNG in its tanks, with 3316.5 10^3 m^3 LNG, which is more than double the volume of France's tanks (1340 10^3 m^3 LNG). France has the second-highest capacity with 1277.7 GWh/d. The remaining 26% of the regasification capacity is spread across seven countries, including Belgium, Greece, Poland, Portugal, Germany, Lithuania, and Croatia, with the lowest capacity found at the Krk LNG terminal in Croatia, which has a capacity of 85.5 GWh/d. It is worth mentioning that the LNG terminals located in Finland and Malta are not reported in ALSI TP. The floating LNG Terminal in the port of Inkoo (Finland) started operations in January 2023.

Figure 21 can be used to keep track of monthly changes in LNG send-out flows for all EU Member States with LNG terminals. France, Spain and the Netherlands represent around 55-69% of the total LNG send-out flow that goes to the European Union, being 55% the lowest monthly share of these countries in June 2022 due to a reduction of flows from the French LNG terminals. This figure also shows the start of the operation of the Wilhelmshaven LNG Terminal 1 (FSRU) in Germany in December.

Figure 21. Monthly LNG send-out flow per EU Member State in 2022.

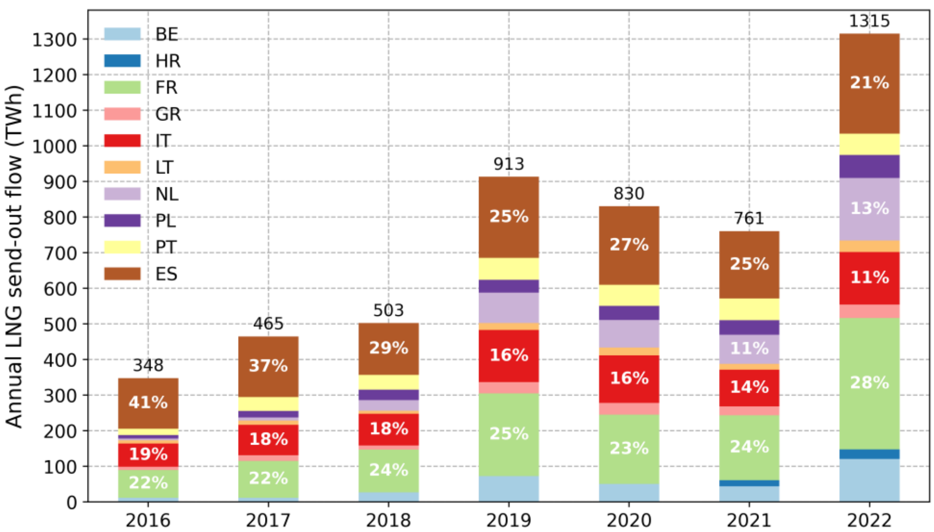


Source: JRC based on ALSI Transparency Platform, 2023.

Looking at the historical data, the annual LNG send-out flow in the European Union increased dramatically in 2022 (1315 TWh) compared to the last 6 years (2016-2021), as can be seen in Figure 22. This represents an increase of 73% with respect to the LNG flow in 2021 and more than double of the 6-year annual average (636.7 TWh). The annual LNG send-out flows in Spain, France and Italy represented 71-77% of the total in the European Union during years 2016-2018. Since 2019, this share has steadily decreased, down to 60% in 2022, because of several reasons:

- The operation of new LNG terminals in France (Dunkerque on 15 December 2016), Lithuania (FSRU Independence on 7 April 2016), Poland (Świnoujście on 31 May 2016), and Croatia (Krk on 1 January 2021).
- The increasing use of the Dutch LNG terminal since the end of 2019. Moreover, there is a new LNG terminal in the Netherlands, i.e. EemsEnergy, whose operation started on 16 September 2022.
- The regasification expansion capacity of the LNG terminals Revythoussa in Greece (10 April 2019) and Zeebrugge in Belgium (22 July 2020).

Figure 22. Annual LNG send-out flow (TWh) per country along with percent share of each country.



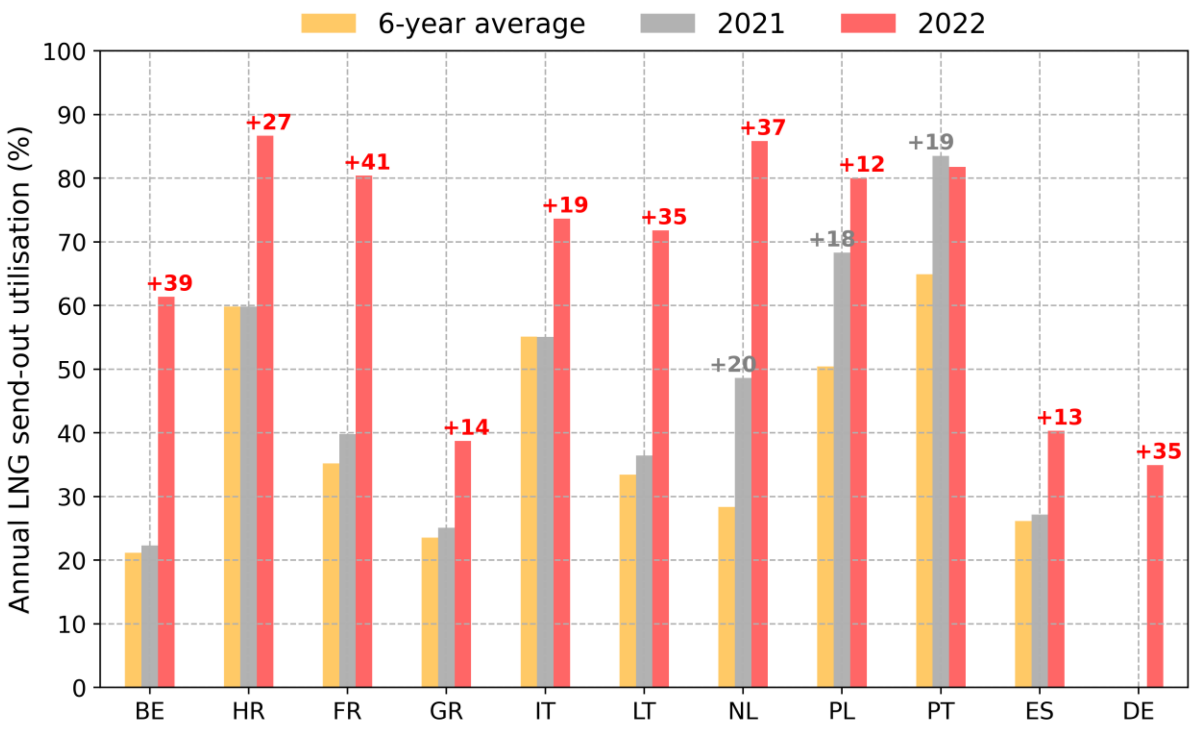
Source: JRC based on ALSI Transparency Platform, 2023.

Figure 23 displays the annual LNG send-out flow utilisation across various EU countries for 2022, 2021, and the average of 2016-2021. On top of the grey bars, we provide the increase in percentage points of the LNG utilisation in 2021 with respect to the average of the last 6 years if this increase is greater than 10 p.p. Likewise, an increase greater than 10 p.p. in 2022 with regard to 2021 is indicated on top of the red bars. Note that the 6-year average for Croatia remains the same as in 2021 since the Krk LNG facility started operations in 2021.

On average, the LNG utilisation remains below 65% in all countries. However, in 2021, Poland, Portugal, and the Netherlands saw an increase of 18-20 p.p. in their LNG utilisation, resulting in an LNG send-out utilisation factor above 65% for Poland and Portugal's LNG terminals. In 2022, most countries with LNG facilities, except Portugal, increased their LNG usage to offset the lack of Russian gas. Even then, Portugal managed to maintain a utilisation factor greater than 80% of the corresponding LNG regasification capacity.

The largest changes in LNG utilisation in 2022 were found in France (+41 p.p.), Belgium (+39 p.p.), the Netherlands (+37 p.p.), and Lithuania (+35 p.p.). Croatia (+27 p.p.), Italy (+19 p.p.), Greece (+14 p.p.), Spain (+13 p.p.), and Poland (+12 p.p.) witnessed moderate increases. Consequently, the LNG utilisation in 2022 has stayed above 70% in seven out of eleven EU Member States with LNG facilities. Additionally, the German LNG terminal began operations in December 2022, with an average LNG utilisation of 35% during the operating period.

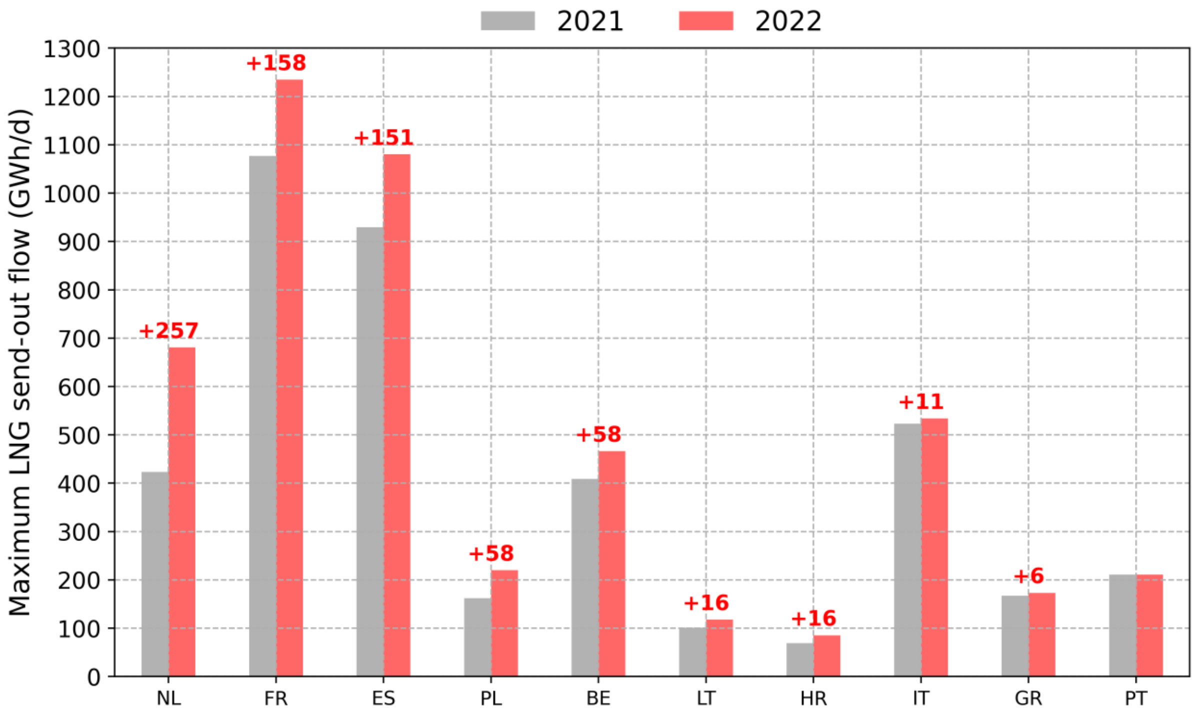
Figure 23. Annual LNG send-out utilisation by European Union country in 2022, 2021, and 6-year average (2016-2021). The text in grey on top of the bar indicates the increase in percentage points with respect to the 6-year average and the text in red shows the increase in percentage points with respect to 2021. Values below 10 p.p. are not shown.



Source: JRC based on ALSI Transparency Platform, 2023.

Figure 24 represents the maximum LNG send-out flow per country observed from 2016 until 2021 (in grey) and 2022 (in red). To ensure that the values do not exceed the regasification capacity, the maximum LNG send-out flow is calculated as the 99th percentile of the corresponding time series. The numerical values of this figure can be found in Annex 2. At the EU level, the maximum LNG flow recorded until the end of 2021 was 3245 GWh/d. However, by the end of 2022, the maximum flow had increased by 29.6% to 4205 GWh/d. The most significant changes at the country level were observed in the Netherlands, France, and Spain, where the maximum LNG send-out flows increased by 257, 158, and 151 GWh/d, respectively. In all other countries (except Portugal), there were positive changes, indicating that the record for daily regasification flows had been surpassed in 2022.

Figure 24. Maximum LNG send-out flow up to the end of 2021 and 2022 by country. The text in red represents the increase in GWh/d in 2022 compared to 2021. Values below 5 GWh/d are not shown.



Source: JRC based on ALSI Transparency Platform, 2023.

3.3 Liquefied natural gas facilities in the European Union

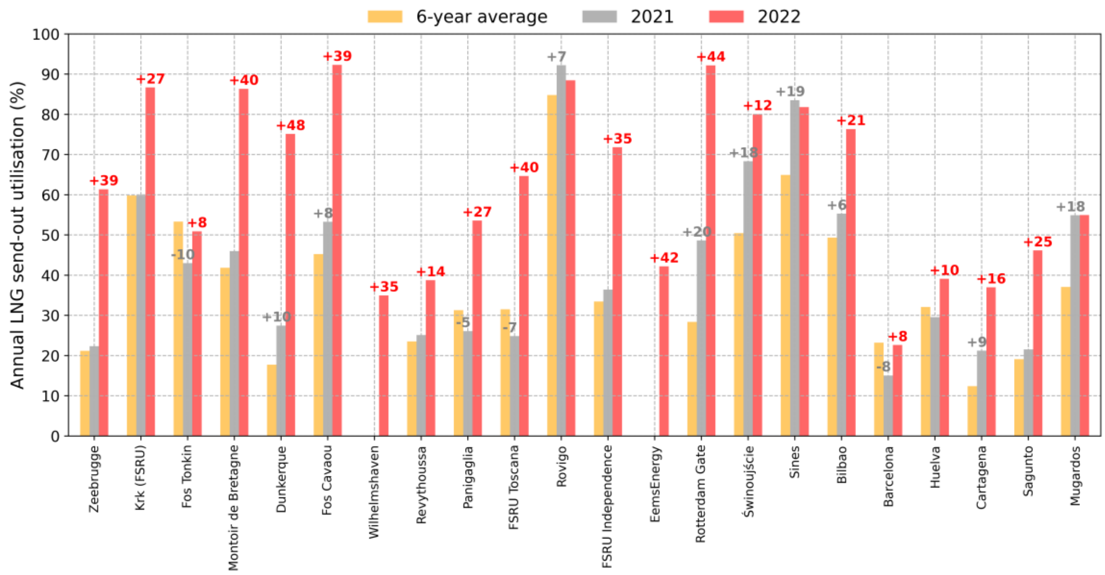
Currently, there are 22 LNG facilities in the European Union. Two of these facilities, Wilhelmshaven in Germany and EemsEnergy in the Netherlands, commenced operations at the end of 2022. Of all EU countries, Spain has the most LNG terminals, with six facilities in its territory, including Bilbao, Barcelona, Huelva, Cartagena, Sagunto, and Mugardos. France and Italy follow with four and three facilities, respectively.

Figure 25 provides the annual LNG send-out utilisation per facility for 2022, 2021, and the average in the years 2016-2021. The average utilisation rates in 2016-2021 were below 50% in all terminals except Krk (Croatia), Fos Tonkin (France), Rovigo (Italy), and Sines (Portugal). LNG facility Krk (Croatia) reached 60% and there is only data for one out of the 6 years (2021). Rovigo (Italy) had a utilisation rate above 80%, while Sines (Portugal) reached around 65%. The Polish LNG facility Świnoujście, Bilbao (Spain) and Fos Tonkin (France) had rates around 50%. Some LNG facilities increased their utilisation rate in 2021 compared to the 6-year average, such as Dunkerque and Fos Cavaou LNG terminals in France (+10 and +8 p.p., respectively), Rovigo LNG terminal in Italy reaching an annual utilisation factor beyond 90%, and Bilbao and Cartagena (Spain) with increases up to 6 and 9 p.p., respectively. Moreover, Rotterdam Gate (the Netherlands), Świnoujście (Poland), Sines (Portugal), and Mugardos (Spain) LNG facilities substantially increased their utilisation rates in 2021 by 18-20 percentage points with respect to the 6-year average. However, slight reductions were identified in some LNG terminals in 2021, such as in Fos Tonkin (France), Panigaglia and FSRU Toscana (Italy), and Barcelona (Spain).

In 2022, most of the LNG terminals witnessed a considerable increase in their utilisation rates to counterbalance the gas shortage from the East. LNG terminals in Rovigo and Sines were still characterised by their high utilisation rates beyond 80%, and Mugardos LNG terminal saw the same rate as in 2021, around 55%. Notably, 12 out of 22 terminals achieved utilisation rates greater than 60%, and 13 of them experienced increases between 20-48 percentage points compared to 2021.

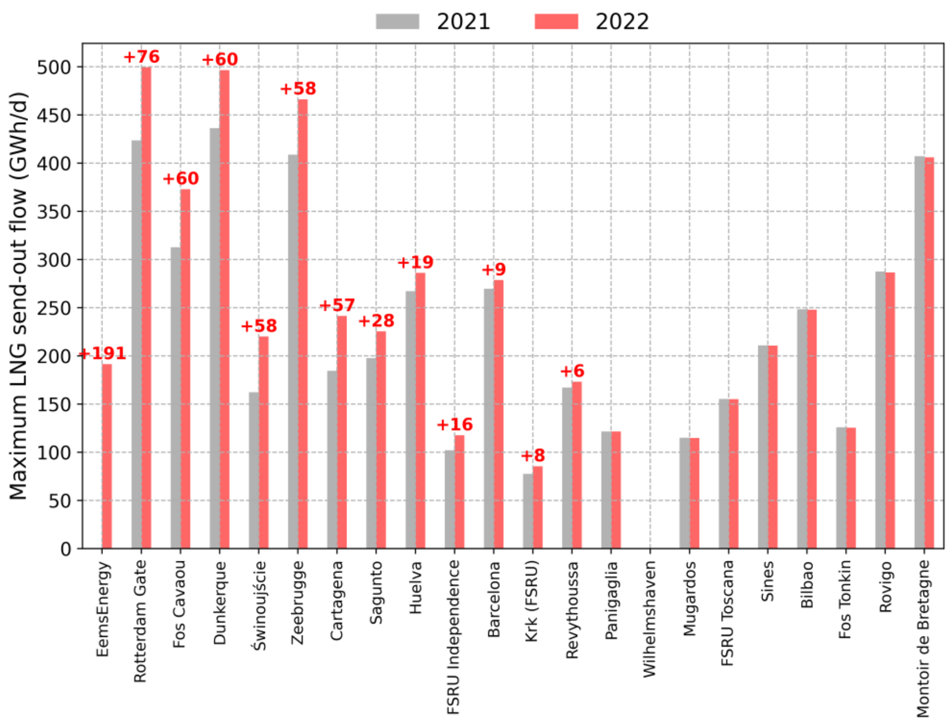
Figure 26 shows the maximum LNG send-out flow per facility observed from 2016 until 2021 (in grey) and 2022 (in red). To ensure that the values do not exceed the regasification capacity, the maximum LNG send-out flow is calculated as the 99th percentile of the corresponding time series. The numerical values of this figure can be found in Annex 2. Out of the 20 terminals (29), eight did not experience any change in their maximum values: Panigaglia, FSRU Toscana and Rovigo (Italy), Sines (Portugal), Mugardos and Bilbao (Spain), and Fos Tonkin and Montoir de Bretagne (France). The remaining facilities experienced increases between 5-36% in 2022 compared to 2021.

Figure 25. Annual LNG send-out utilisation by LNG facility in 2022, 2021, and 6-year average (2016-2021). The text in grey on top of the bar indicates the increase in percentage points with respect to the 6-year average and the text in red shows the increase in percentage points with respect to 2021. Values above -5 and below +5 p.p. are not shown.



Source: JRC based on ALSI Transparency Platform, 2023.

Figure 26. Maximum LNG send-out flow in each LNG terminal up to the end of 2021 and 2022. The text in red represents the increase in GWh/d in 2022 compared to 2021. Values below 5 GWh/d are not shown.



Source: JRC based on ALSI Transparency Platform, 2023.

(29) We do not take into account EemsEnergy and Wilhelmshaven which operated for the first time at the end of 2022.

4 Transport data

Transmission system operators (TSOs) have been collecting data on natural gas transport indicators, such as physical flow and pipeline capacities, and making the data publicly available via the ENTSOG Transparency Platform since 2008 ([30]), in accordance with Regulation (EC) № 715/2009. The dataset extends throughout the European Union, in addition to Ukraine, Moldova, Switzerland, the Western-Balkans, and the UK. TSOs also use the platform to communicate planned and unplanned interruptions of service. The following indicators are provided by the transparency platform for each connection point in daily and/or hourly resolution:

- Physical gas flow in kWh/d: Natural gas flow through the pipeline per gas day.
- Nomination in kWh/d: Nominated (planned) natural gas flow.
- Re-nomination in kWh/d: Adjusted natural gas flow nomination.
- Allocation in kWh/d: Allocated gas flow.
- GCV in kWh/Nm^3: Gross Calorific Value.
- Wobbe index in kWh/Nm^3: Gas interchangeability indicator.
- Firm / interruptible capacity (total, booked, and available) in kWh/d.: Flow capacity guaranteed to be supplied by the TSOs / supply that may be suspended.
- Firm and interruptible capacity interruptions (planned, unplanned, and actual) in kWh/d.
- Data status, which can be provisional or confirmed.

We download these data on a daily or weekly basis via the API using the requests library and process them using Python 3.8 in various Jupyter notebooks ([31]). The eurogastp library ([32]) provides the basis for the download and processing of the dataset.

The dataset shown below spans from 1 January 2020 to 31 March 2023 and was downloaded from the Transparency Platform on April 2023. Entry and exit flows at each connection point do not necessarily correspond in the dataset, so an aggregation strategy was defined for each point applying the following procedure: choice of one direction value, the minimum, the maximum, or the average value, as explained in Section 3.4 of (Jung, et al., 2022). The reader is referred to Jung et al. (2022) for further information on the processing tools that can be used to analyse these data (Jung, et al., 2022).

Individual pipeline flows are aggregated to routes and corridors according to the eurogastp library and flow maps were created in ArcGIS Pro using the arcpy library ([33]).

As explained before, firm capacity is defined as the flow capacity guaranteed by the TSOs, and the fraction of the daily recorded flow over this firm capacity represents the pipeline utilisation. As the firm capacity time series are irregular and influenced not only by technical, but also by market factors, we defined each pipeline's firm capacity as the respective 95th percentile of the daily values recorded in 2022.

As TSOs may offer additional, interruptible capacities, the daily flow may exceed the daily firm capacity, thus increasing the utilisation above 100%.

An overview of the EU natural gas system and its main import routes is shown in Annex 3.

4.1 Pipeline imports from non-EU countries

The changes in the geopolitical context of the EU gas supply between 2020 and 2023, especially since the energy crisis started in the last quarter of 2021, have heavily affected the distribution of natural gas imports from non-EU countries.

Import deficits from the Eastern corridor were partially replaced via increased flows on the remaining routes including flows from LNG facilities. Figure 27 shows the development of the EU import distribution over five gas seasons from 1 October 2020 to 31 March 2023, i.e., three gas winters and two gas summers. The most

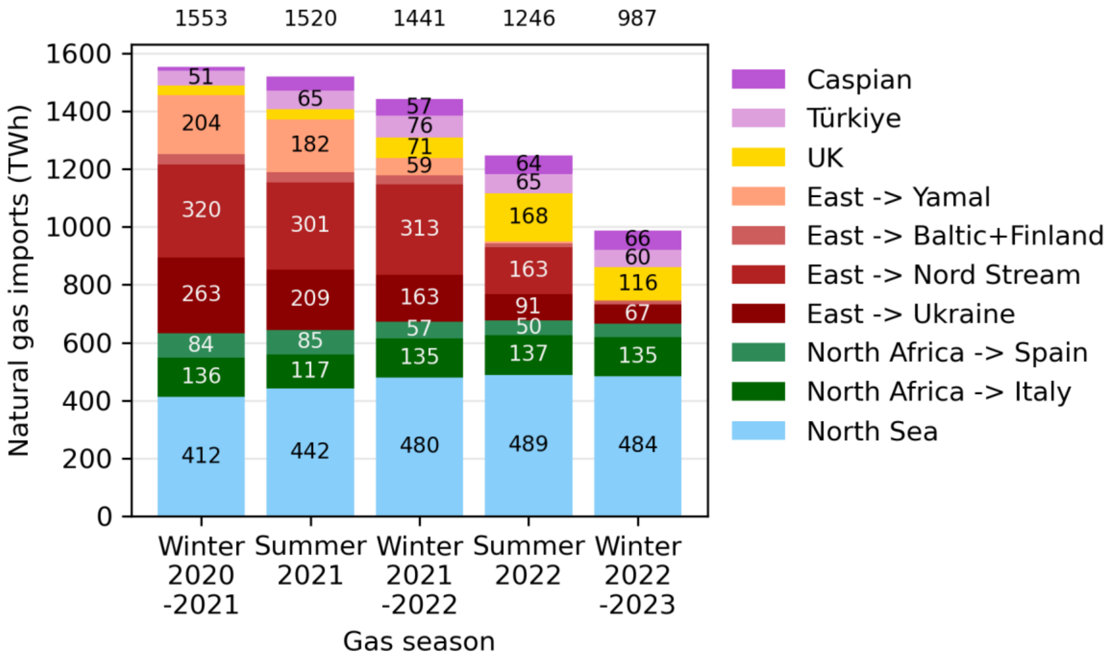
([30]) https://transparency.entsog.eu/.
([31]) https://jupyter-notebook.readthedocs.io/en/stable/notebook.html.
([32]) https://github.com/ec-jrc/eurogastp.
([33]) https://www.esri.com/en-us/arcgis/products/arcgis-python-libraries/libraries/arcpy.

notable changes are the effective cessation in imports along the Nord Stream, Eastern Yamal, and Baltic + Finland routes, which originally (in winter 2020-2021) contributed shares of 20%, 13%, and 2% of total EU imports flows, respectively. Note that there is still gas flowing through the route Baltic + Finland, which goes to the Russian enclave Kaliningrad.

Imports along the Ukraine and Nord Stream routes dropped from a total share of 38% (winter 2020-2021) to 20% in summer 2022 and 7% in winter 2022-2023. These deficits were partially offset by significantly increased imports via the North Sea and UK routes, as well as smaller increases via the Caspian and Türkiye routes.

Overall pipeline imports decreased by 274 TWh, or 18%, between the gas summers of 2021 and 2022, and by 566 TWh, or 36%, between the gas winters of 2020-2021 and 2022-2023. This has been offset by an increased LNG supply to the European Union, as seen previously in Figure 22.

Figure 27. Natural gas imports by route for summer and winter gas seasons between 2020 and 2023. Total imports per season are displayed above the graph. Numerical values of flows below 50 TWh are not shown.



Source: JRC based on ENTSOG Transparency Platform, 2023.

Figure 28 compares the import pipeline utilisation during the gas summer 2021 and 2022 ([34]). Imports from Belarus and Russia ceased completely during the gas summer season of 2022, although the transport flow from Belarus to Kaliningrad (Russia) continued with a median utilisation factor of 0.49 on the Lithuania-Russia pipeline, down from 0.57 in the previous year.

On 26-27 April 2022, Russia halted gas supplies to Poland and Bulgaria ([35]), thus decreasing the median utilisation factor of the Yamal-Europe route from 0.6 in summer 2021 with a narrow variability to essentially 0 in summer 2022. Shortly after this cut-off, Russia stopped flows to Finland due to an energy payment dispute ([36]). This is visible by the reduction of the median utilisation factor from 0.18 in summer 2021 to 0 in 2022.

In mid-June 2022, Gazprom cut supplies to Europe via Nord Stream 1 by reducing its capacity to just 40% due to maintenance issues with a key compressor station. Nord Stream 1 was completely closed for its annual maintenance shutdown on 11-21 July 2022 ([37]). Close to the start of the heating season (26

([34]) The median has been used throughout this section to discuss the pipeline utilisation for the sake of convenience because the reader can relate the analysis with the median shown in the corresponding boxplots.
([35]) https://www.reuters.com/world/poland-bulgaria-face-russian-gas-cut-ukraine-crisis-escalates-2022-04-26/.
([36]) https://www.reuters.com/business/energy/russia-stops-finland-gas-flow-over-payments-dispute-2022-05-21/.
([37]) https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/natural-gas/070422-russian-gas-supply-to-europe-plummets-in-june-as-nord-stream-flows-slashed.

September 2022), gas deliveries via Nord Stream 1 were stopped permanently due to the rupture of both pipelines Nord Stream 1 and Nord Stream 2 in the Baltic Sea, near the island of Bornholm ([38]). All in all, it can be observed a dramatic reduction of the median utilisation factor in Nord Stream 1 from 1.26 (with a very narrow variability) in summer 2021 to 0.5 in summer 2022.

At the end of July 2022, Gazprom stopped also gas deliveries to Latvia ([39]). The Russia-Latvia pipeline utilisation decreased to 0.07 in summer 2022 while its median utilisation was 0.35 in summer 2021.

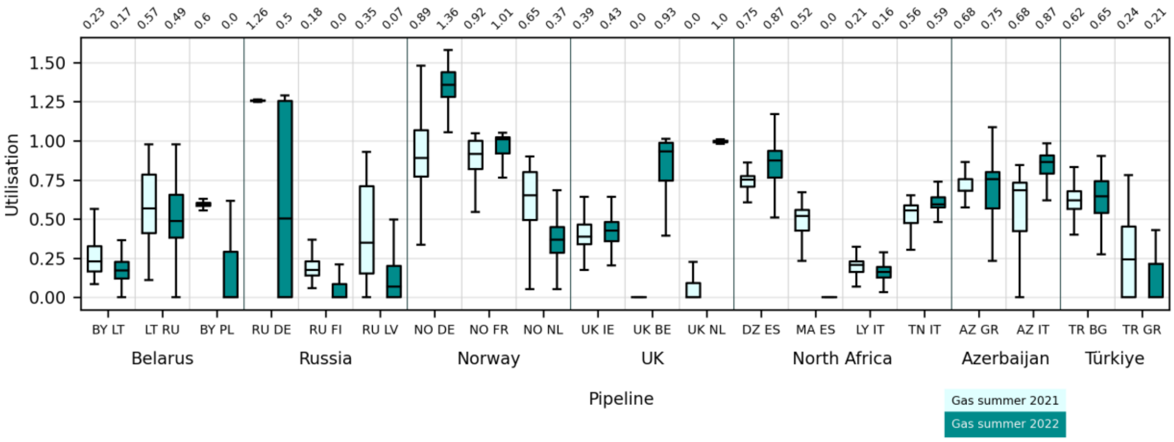
Regarding the North Sea route, pipeline utilisation from Norway to Germany increased from 0.86 to an overutilisation of 1.36. Similarly, gas deliveries from Norway to France increased from a median utilisation of 0.92 to 1. However, the gas deliveries to the Netherlands reported reductions in utilisation during this period, being the pipeline utilisation 0.65 in summer 2021 and 0.37 in summer 2022.

Large increases in imports from the United Kingdom were recorded by Belgium and the Netherlands, from a median utilisation of 0 in summer 2021 to 0.93 and 1 during summer 2022, respectively.

Supplies to Morocco were cut off completely following the expiration of the contract (on 31 October 2021) for the Gaz Maghreb Europe (GME) pipeline connecting Algeria with Spain via Morocco ([40]) (see median utilisation of 0 in summer 2022 in Figure 28). This has been partially compensated with an increase of flows through Medgaz pipeline connecting directly Algeria with Spain via the entry point of Almeria. In summer 2022, the median utilisation was 0.87, more than 10 percentage points higher than the one observed in summer 2021.

Increased flows from Azerbaijan and Türkiye were observed in summer 2022 compared to the ones in summer 2021.

Figure 28. Pipeline utilisation at relevant EU import routes during the gas summers of 2021 and 2022. Median utilisation values are displayed above the graph.



Source: JRC based on ENTSOG Transparency Platform, 2023.

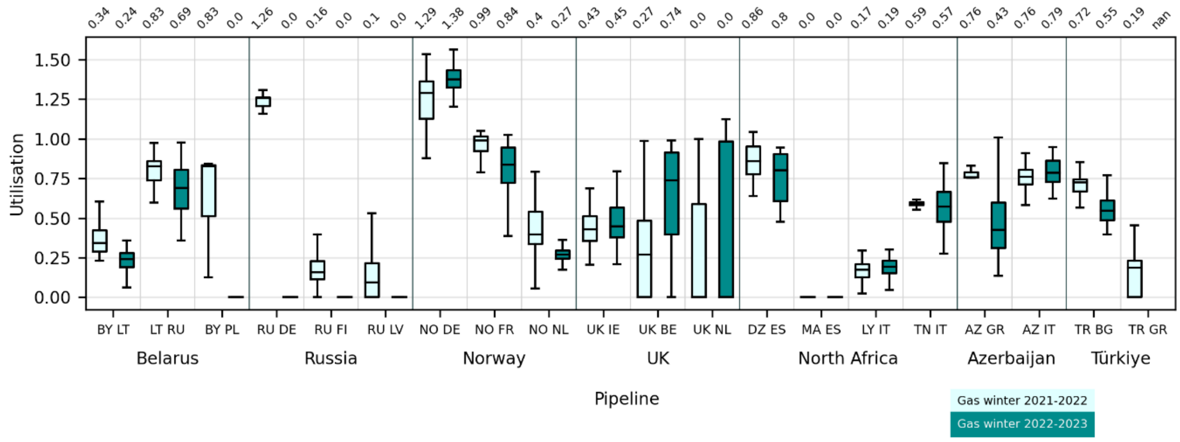
Figure 29 compares the import pipeline utilisation during the gas winter 2021-2022 and 2022-2023. The trend described in summer can be reflected, and even stressed, in winter. Note that the total inflows to the European Union decreased by 32% in winter 2022-2023 compared to the previous winter season. Hence, it is clearly visible the interruption of deliveries from Nord Stream, Yamal, and Baltic + Finland routes (see interconnection points of Belarus-Poland, Russia-Germany, Russia-Finland, and Russia-Latvia).

While pipeline utilisation from Norway to Germany increased from 1.29 to a further overutilisation of 1.38, France and the Netherlands reported reductions in utilisation during this period up to 0.84 in France and 0.27 in the Netherlands. Large increases in imports from the UK were recorded by Belgium from a median utilisation of 0.27 in winter 2021-2022 to 0.74 in winter 2022-2023. Finally, the imports from Azerbaijan to Greece decreased significantly in winter 2022-2023 to a median pipeline utilisation of 0.43, down from 0.76 in the winter 2021-2022, although the total import flows from Caspian increased by 9 TWh.

([38]) https://www.reuters.com/business/energy/nord-stream-ruptures-revealed-europe-grapples-with-gas-plan-2022-10-18/.
([39]) https://www.reuters.com/business/energy/gazprom-says-it-halts-gas-supplies-latvia-2022-07-30/.
([40]) https://www.euractiv.com/section/energy/opinion/why-cant-algeria-solve-europes-gas-woes/.

As can be seen in Figure 27, import flows from Türkiye decreased by 16 TWh during this period: no flows were recorded on the Türkiye-Greece route during the winter 2022-2023.

Figure 29. Pipeline utilisation at relevant EU import routes during the gas winters of 2021-2022 and 2022-2023. Median utilisation values are displayed above the graph.



Source: JRC based on ENTSOG Transparency Platform, 2023.

4.2 Intra-EU physical flows

The development of EU natural gas imports and the changes in the distribution of import countries also changed the net flow magnitudes and directions between EU countries.

Figure 30 represents the total intra-EU physical natural gas flows during the gas summer of 2022. The figure highlights new and reversed net gas flows between EU countries comparing the gas summers of 2021 and 2022. Orange arrows indicate new or reversed flows, while grey arrows indicate flows with unchanged directions.

Utilisation in the pipeline from Germany to Poland increased from a median of 0.21 to a median of 0.53. This reversed flow resulted from the reduction in East corridor gas imports. Germany also increased its imports of natural gas from the Netherlands in 2022 after being a net importer in 2021. Flows previously routed from France to Portugal and Spain in 2021 were also reversed in 2022, with France now supplying Belgium with natural gas as well.

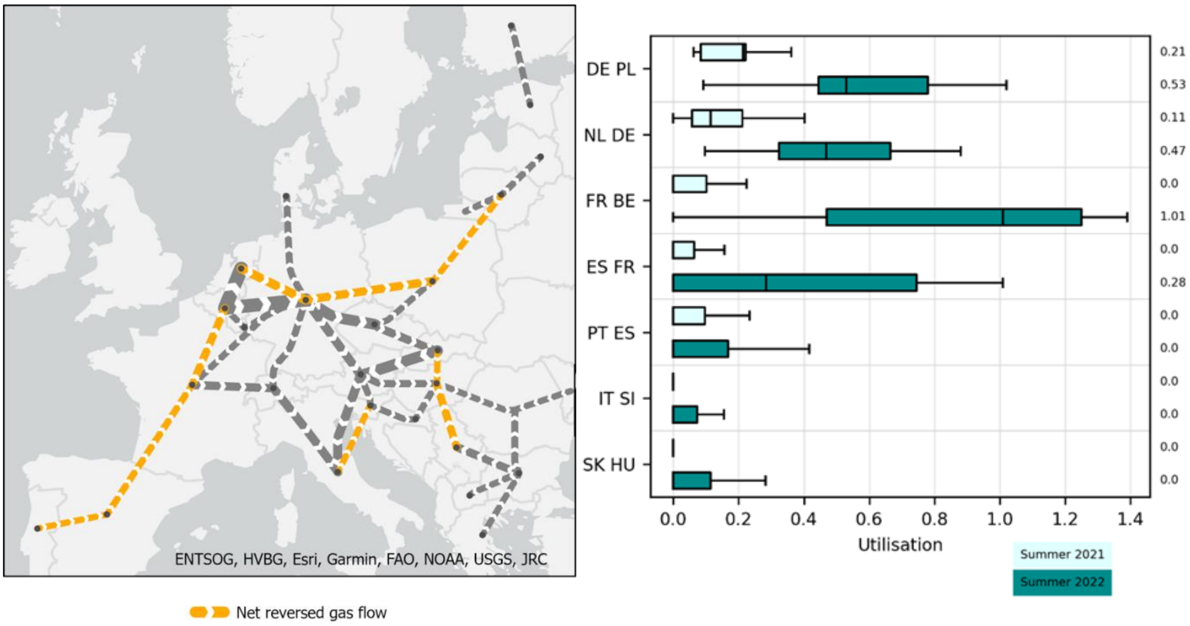
These northward flows were supported by increased LNG imports to France and Spain (see section 3.2). It is remarkable the higher volatility of intra-EU flows in the gas summer of 2022 in these cross-border transmission pipelines (DE-PL, NL-DE, FR-BE and ES-FR) compared to 2021.

A similar trend is shown in Figure 31 and Figure 32 when comparing the last three winter seasons. Figure 31 shows net import flows from Belgium and the Netherlands to Germany, as well as the flows from France to Belgium and from Belgium to the Netherlands, which were reversed in the gas winter of 2021/2022 respective the gas winter of 2020/2021.

A major increase in volatility is reported for almost all pipelines, and particularly for the ones connecting France to Belgium, Belgium to the Netherlands, and Belgium to Germany. These routes also report extreme values exceeding significantly the maximum utilization of capacity, which may happen when additional interruptible capacity is supplied.

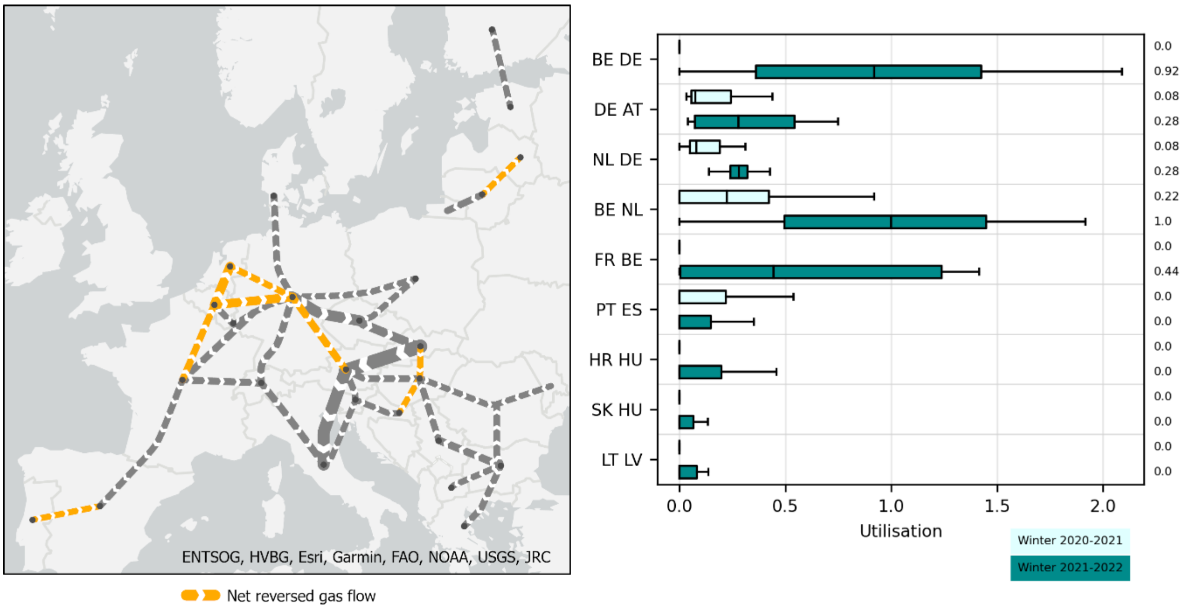
Germany also became a net exporter of natural gas to Austria. In winter 2022-2023 (Figure 32), Spain, Greece and Italy, which increased their LNG utilisation in 2022 by 13, 15, and 19 percentage points compared to 2021, became net exporters to France, Portugal, Bulgaria, and Slovenia.

Figure 30. Intra-EU physical natural gas flows during the gas summer of 2022 (left) and utilisation values of pipelines with reversed flow during this time frame (right). Net flow reversals and new flows respective the gas summer of 2021 are highlighted in orange. Flow magnitude and direction are represented by the size and direction of the arrows. Median utilisation values are displayed on the far right.



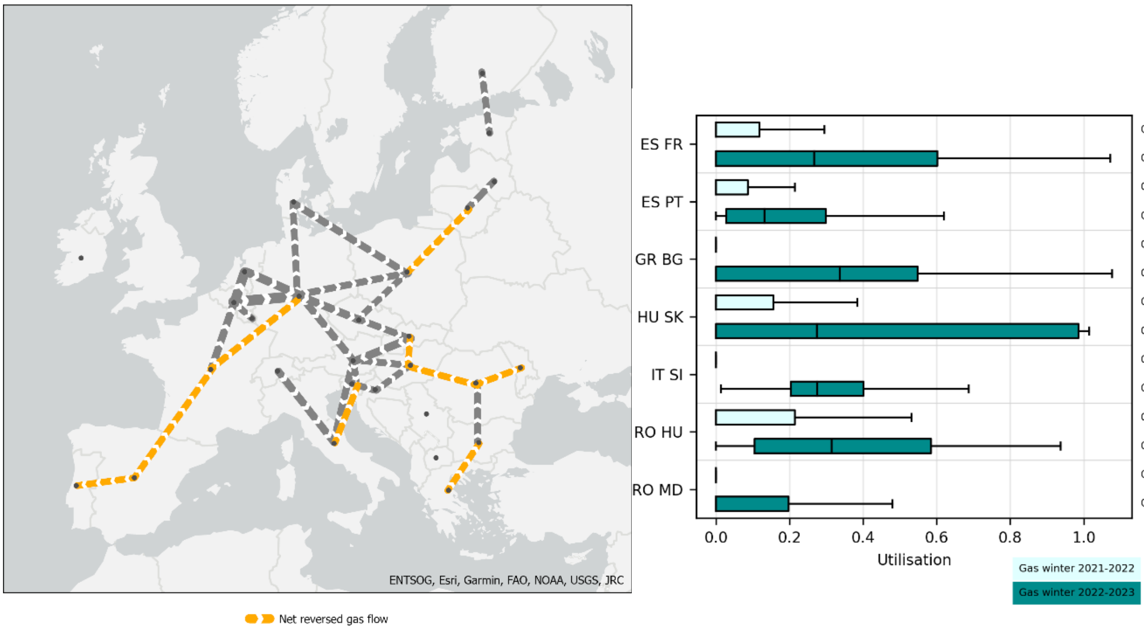
Source: JRC based on ENTSOG Transparency Platform, 2023.

Figure 31. Intra-EU physical natural gas flows during the gas winter of 2021/2022 and utilisation values of pipelines with reversed flow during this time frame (right). Net reversed flows and new flows respective the gas winter of 2020/2021 are highlighted in orange. Flow magnitude and direction are represented by the size and direction of flows. Median utilisation values are displayed on the far right.



Source: JRC based on ENTSOG Transparency Platform, 2023.

Figure 32. Intra-EU physical natural gas flows during the gas winter of 2022/2023 and utilisation values of pipelines with reversed flow during this time frame (right). Net reversed flows and new flows respective the gas winter of 2021/2022 are highlighted in orange. Flow magnitude and direction are represented by the size and direction of flows. Median utilisation values are displayed on the far right.



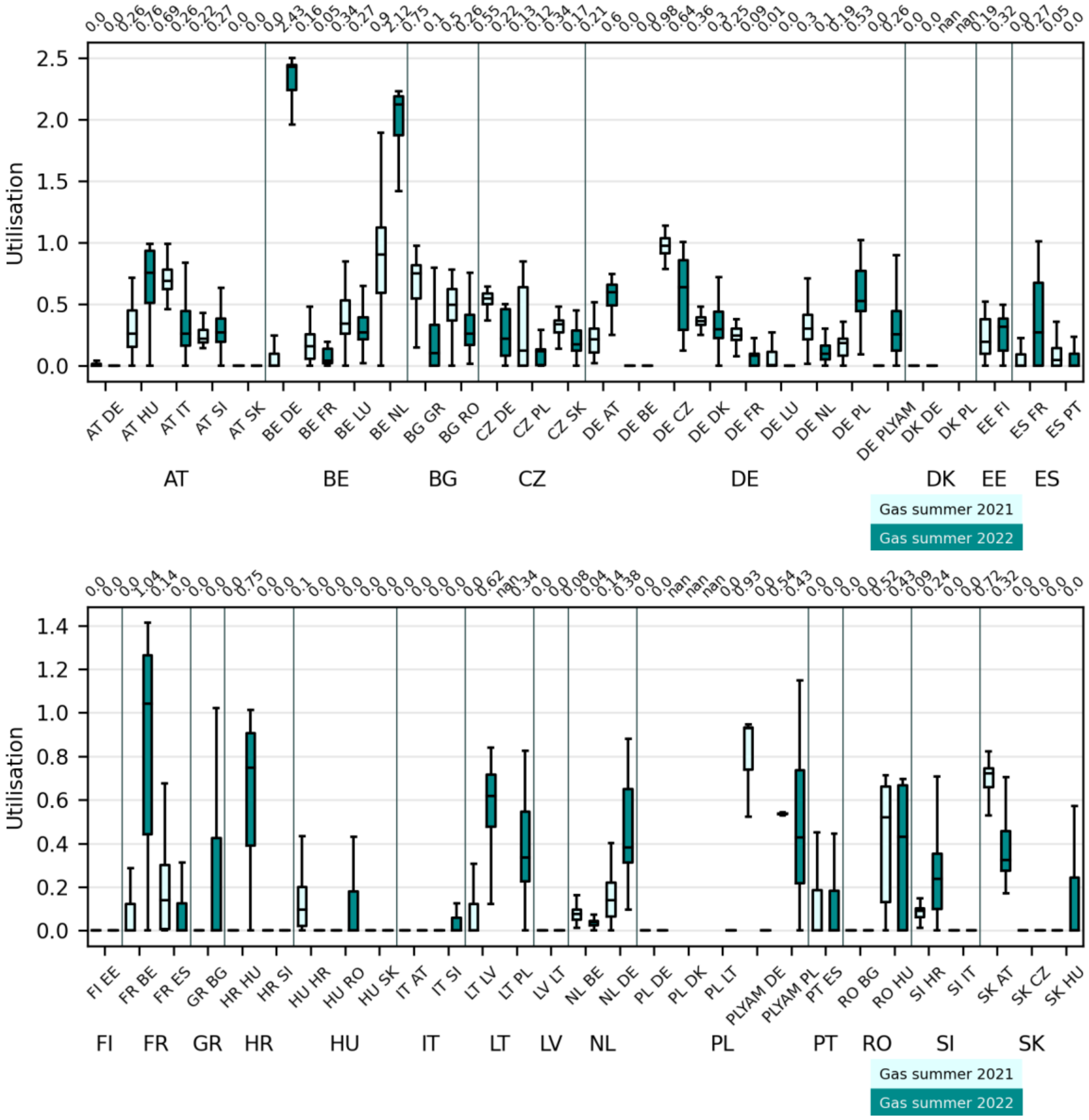
Source: JRC based on ENTSOG Transparency Platform, 2023.

Figure 33 represents the pipeline utilisation between EU countries during the last two gas summer seasons (2021 and 2022), whereas Figure 34 shows it for the gas winter 2021-2022 and 2022-2023.

Overall, median utilisation remains below 100%, except for the aggregated interconnection points of Belgium-Germany, Belgium-Netherlands, and France-Belgium. The highest utilisation (median of 2.43) can be found in the pipeline to Germany from Belgium during the summer season, where LNG send-out (see section 3.2) and UK imports increased significantly in 2022.

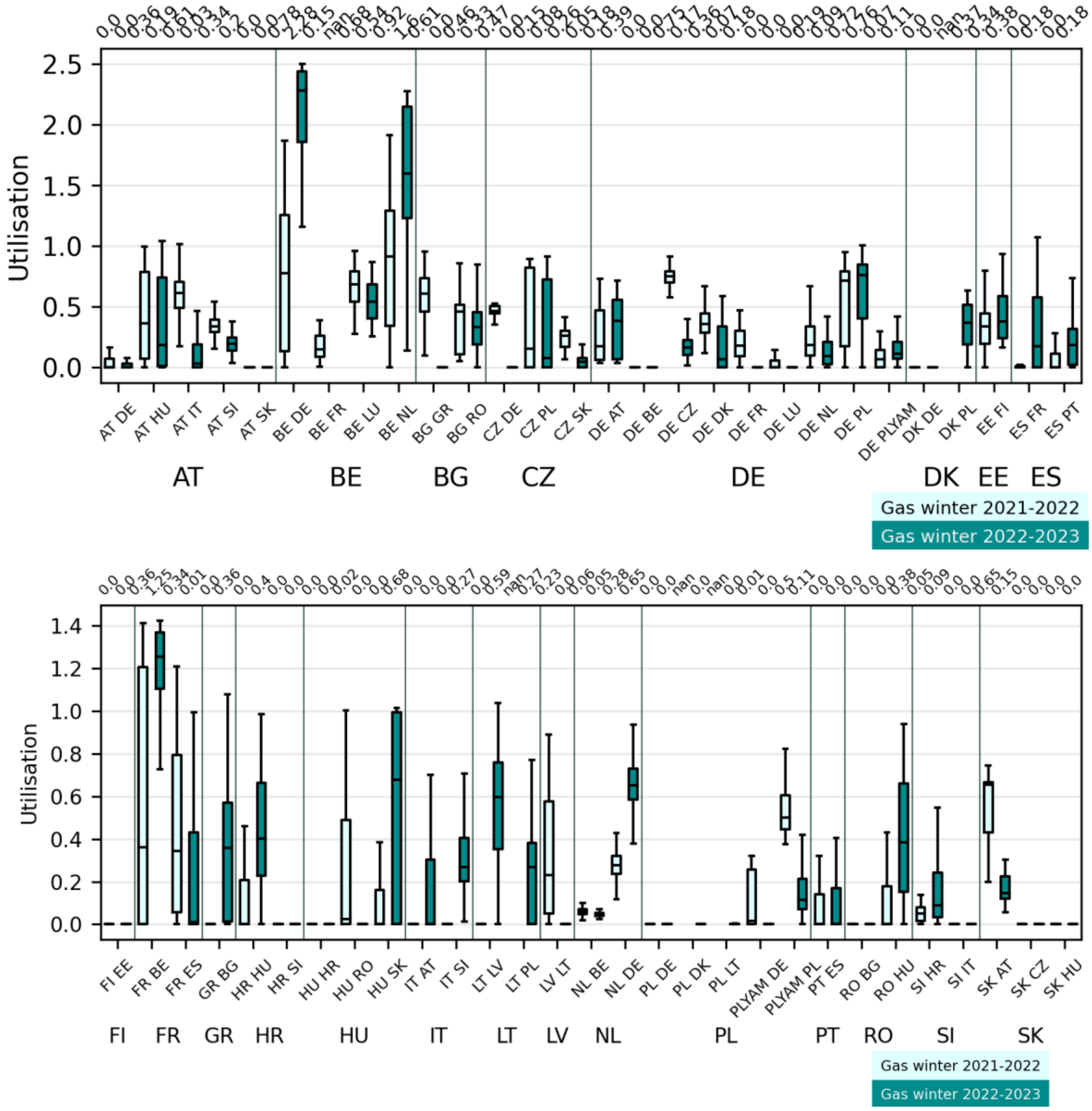
The start of the operation of the Baltic Pipe by the beginning of the winter 2022-2023 is reflected in Figure 34 in which the median pipeline utilisation of the interconnector Denmark-Poland was 0.37. This interconnector allowed Norway to route gas to Poland via Denmark.

Figure 33. Pipeline utilisation between EU countries during the gas summer of 2021 and 2022. Median values are shown above the graphs.



Source: JRC based on ENTSOG Transparency Platform, 2023.

Figure 34. Pipeline utilisation between EU countries during the gas winter of 2021-2022 and 2022-2023. Median values are shown above the graphs.



Source: JRC based on ENTSOG Transparency Platform, 2023.

5 Gas consumption

The JRC published in 2021 the European Natural Gas Demand (ENaGaD) database ([41]) (Zaccarelli, Giaccaria, Feofilovs, & Bolado-Lavín, 2021), which contains the daily national consumption of natural gas in the EU Member States and some European countries. The information comes mainly from the transmission system operators of the countries complemented with data from ENTSOG whenever necessary. The data consumption for Slovakia is not publicly available; it is collected by the Slovak Competent Authority and shared with the JRC. ENaGaD is updated internally on a continuous basis and the daily time series span currently from 1 January 2015 to 31 January 2023. Another major characteristic of ENaGaD is the sectorial decomposition of the national gas consumption. This breakdown is not homogeneous across the European countries. Table 6 explains this decomposition in main categories: consumption of power generation users (power plants), consumption of residential and commercial users (distribution) and consumption of industrial users (industry). The category *Other* represents the difference between the total consumption and the identified category present in the MS breakdown. For the MS for which the category consumption of power plants does not exist, an estimation might be calculated using the monthly Eurostat data. Indeed, besides the total inland consumption, Eurostat provides the monthly consumption for electricity and heat generation. The ratio between the latter and the former is the multiplicative factor we need to apply to the *Total* demand to obtain the demand for power plants.

To support this conjecture, Figure 35 shows a comparison between those ratios obtained using ENaGaD and Eurostat data, for Belgium, for the period 2017-2022. We concluded that ratios obtained using Eurostat are a good proxy for the ratios obtained using the ENaGaD data and we will expand ENaGaD database by using this proxy. The comparisons for Austria, Greece, Spain, Ireland, Italy and Portugal (not shown here) are leading to the same conclusion.

The next update of the ENaGaD, spanning from 1 January 2015 to 30 June 2023, will include an extended sectorial breakdown based on this estimation of the gas-fired *Power plants* consumption.

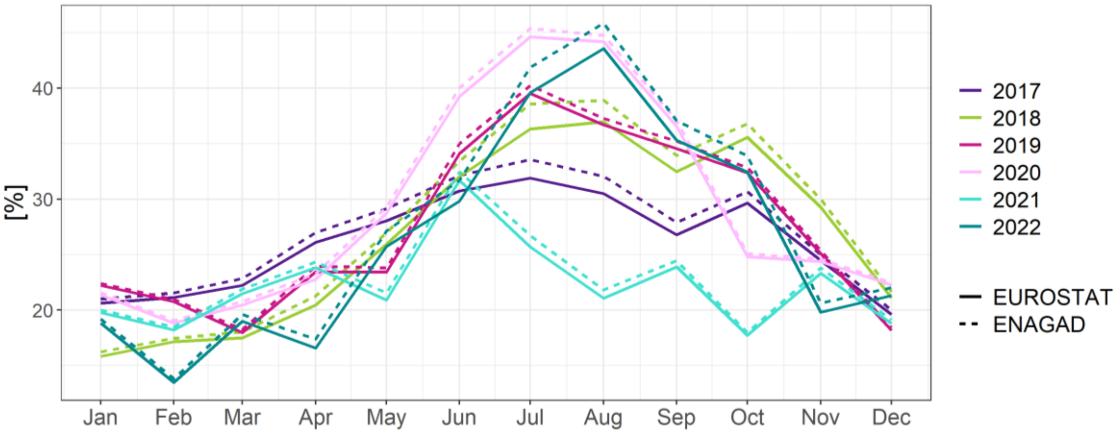
Table 6. Sectorial decomposition of the natural gas consumption in the MS.

Country code	Total	Power plants	Distribution	Industry	Other
AT	x	x			x
BE	x	x	x	x	
BG	x				
CZ	x				
DE	x		x		x
DK	x				
EE	x				
EL	x	x	x	x	
ES	x	x			x
FI	x				
FR	x		x		x
HR	x		x		x
HU	x		x		x
IE	x	x	x	x	
IT	x	x	x	x	
LT	x				
LU	x		x	x	
LV	x				
NL	x		x		x
PL	x		x		x
PT	x	x	x	x	
RO	x		x		x
SE	x				
SI	x				
SK*	x	x	x	x	

Source: ENaGaD database (: not publicly available).*

([41]) https://zenodo.org/record/6364875#.ZF6jClRBw2x.

Figure 35. Comparison between the ratios of gas consumption for power (and heat) generation in the total gas consumption in Belgium using Eurostat and ENaGaD for the period 2017-2022.

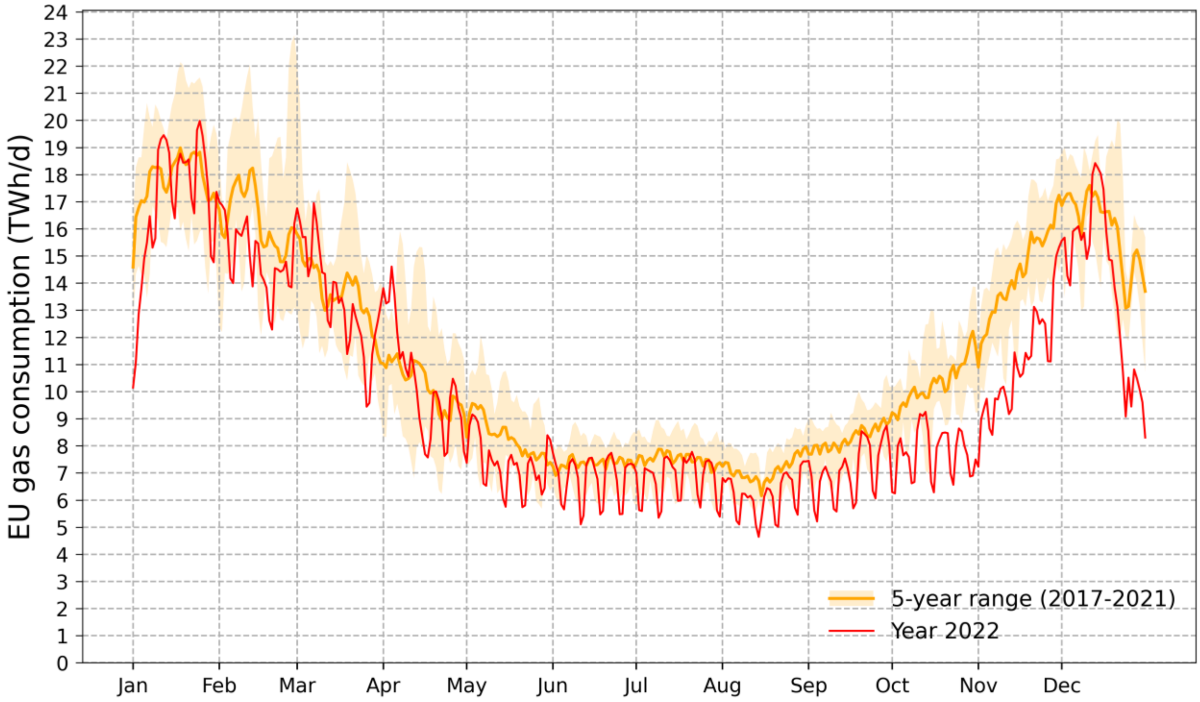


Source: JRC based on ENaGaD and Eurostat, 2023.

As briefly mentioned in the introduction, the Regulation (EU) 2022/1369 for national gas demand reduction to reduce dependency on natural gas supplies from Russia was adopted on 5 August 2022. This regulation recommended a voluntary reduction of 15% since August 2022 until 31 March 2023 with respect to the average of the preceding five years (obviously comprising the same time horizon of eight months). This has been proved a successful preventive/mitigation measure to increase the security of gas supply during winter 2022-2023. In the Staff Working Document (SWD(2023) 63 final, 2023), the Commission provided an analysis of the gas demand reduction since August 2022. For this, the JRC conducted an analysis based on Eurostat and ENaGaD data to determine a breakdown by demand sector and furthermore estimate the demand reduction per sector in August to December 2022 compared to the 5-year average.

This report is focused on the state of play of the EU natural gas system in 2022 compared to the past years. So we will limit our demand analysis to the end of 2022. Despite this limitation, it can be observed in Figure 36 that the demand reduction already took place along the year 2022 to some extent. In the first semester of 2022, there are some periods of consumption below the 5-year average (e.g. most of the days in February, second half of March, or even in May and June). When the Regulation (EU) 2022/1369 on coordinated demand reduction was adopted, the reduction trend has been increased and maintained along the second half of 2022, except for the cold spell that took place in 12-16 December. In short, the EU has reduced its natural gas consumption by 10.9% in 2022 compared to the 5-year average (2017-2021).

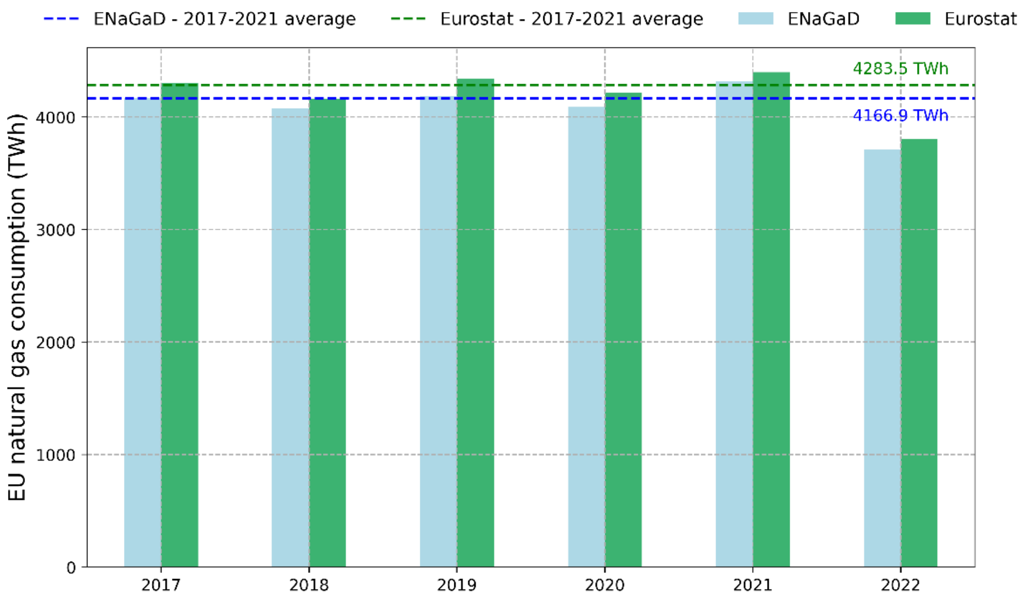
Figure 36. Daily gas consumption in the European Union in 2022 compared with the 5-year average and range (2017-2021).



Source: JRC based on ENaGaD, 2023.

ENaGaD provides systematically lower consumption values than the ones reported by Eurostat. Figure 37 shows the gap in EU gas consumption between ENaGaD and Eurostat, the statistical office of the European Union, on an annual basis since 2017. The annual consumption from ENaGaD is 2-3.5% lower than Eurostat's figures. The two main reasons for this change might be: (i) the biogas/biomethane consumption, and (ii) other off-grid gas consumption. It should be noted that Malta is included in Eurostat, thus adding up 4 TWh per year more than ENaGaD.

Figure 37. Annual natural gas consumption in the European Union from 2017 until 2022 from two data sources (ENaGaD and Eurostat). The dashed lines represent the respective 2017-2021 average.



Source: JRC based on ENaGaD and Eurostat, 2023.

One open question is whether the EU gas consumption has been reduced in all countries by the same proportion. In addition, it would be interesting to know if we can rely on ENaGaD for estimating such reduction despite the gap identified previously. To answer to these questions, Figure 38 represents the relative change of gas demand in 2022 compared to the average 2017-2021. The consumption has been reduced in the EU by far regardless of the data source and in all countries. From ENaGaD, the EU demand reduction is estimated at 10.9%, as mentioned before, while Eurostat ([42]) gives an 11.2% reduction. Therefore, ENaGaD, although providing lower consumption values than Eurostat, may be used for estimating the consumption reduction in the EU. What about at Member State level?

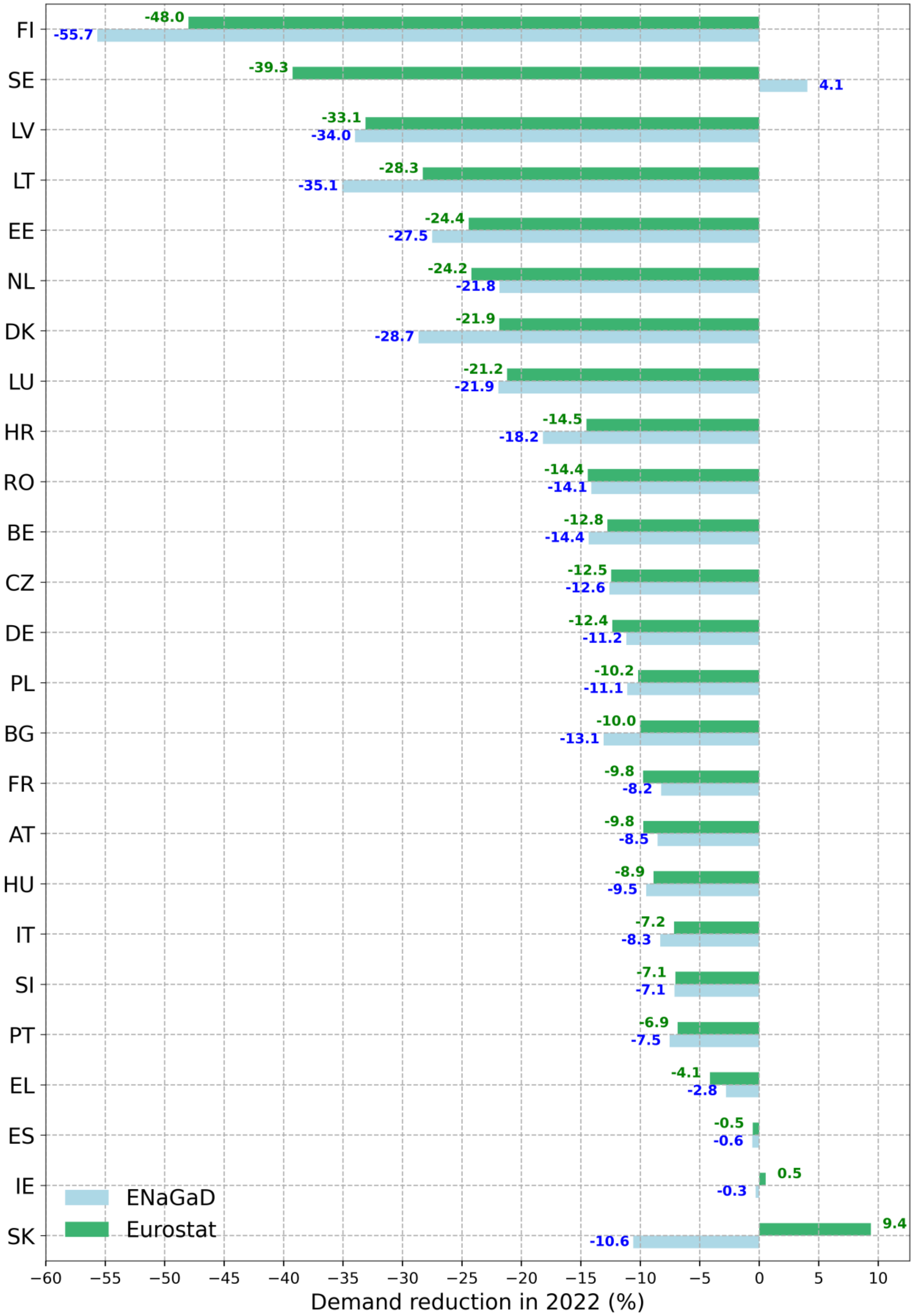
The demand reduction in most of the EU countries is quite close for both databases (ENaGaD and Eurostat). Admittedly, there are some exceptions which deserve some attention:

- ENaGaD overestimates the gas consumption reduction compared to Eurostat values in Finland, Lithuania, Estonia, Denmark, and Croatia. However, their gas consumption represented only 2.7% of the EU demand in 2021 and 2.3% in 2022.
- Sweden provides a gas consumption reduction up to 39% in 2022 in Eurostat while it shows an increase of 4.1% when using ENaGaD data.
- The opposite can be observed in Slovakia. ENaGaD estimates the demand reduction in 11% in 2022 while Eurostat gives rise to an increase of 9% in 2022. However, this difference was due to mistakes in data entries which were reported to Eurostat. Our comparison of the demand data lead to their correction by the responsible entity in Slovakia and was acknowledged by the Ministry of Economy of the Slovak Republic.

It should be noted that both countries, Sweden and Slovakia, represent a very low share of the EU gas consumption (around 0.3% and 1.4% respectively). Therefore, these changes barely affect to the figure at EU level.

([42]) Eurostat in energy units rather than in volumetric units has been used throughout this section.

Figure 38. Changes in gas consumption in 2022 with respect to the 2017-2021 average by EU Member State for two data sources (ENaGaD and Eurostat).



Source: JRC based on ENaGaD and Eurostat, 2023.

6 Monitoring tools

In the previous sections 2-5, we have analysed in detail the operation of the EU's natural gas system during 2022 compared to historical data by using a suite of graphic tools. Some of them are useful to monitor its operation on a daily basis and this section is devoted to compiling them. The monitoring in real time is essential in times of crisis to keep track of any security of gas supply issue that may arise. The list of graphic tools is not exhaustive and other tools are proposed to remain vigilant, for example, on the operation of UGSs and, in general, on the gas supply to the EU. Note that all graphic tools can be resampled to monitor the natural gas system operation at a coarse temporal granularity (weekly or monthly).

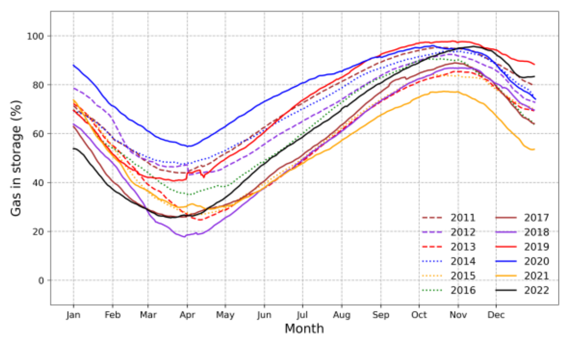
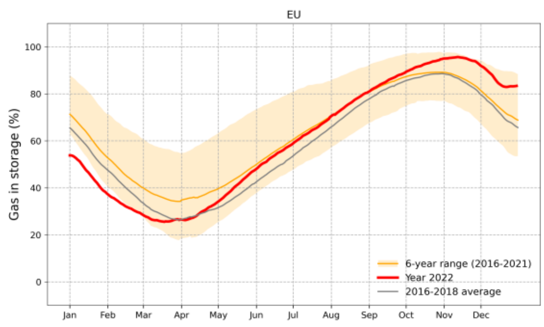
One clarification should be made on the demand side. As stated in Section 5, there are two main sources reporting natural gas consumption data: the statistical office of the EU, Eurostat, and the JRC's in-house ENaGaD database. The former provides data at monthly granularity and with a delay of maximum 55 days after the reference month, which makes it infeasible to monitor it daily. The latter contains data with a finer granularity (i.e. daily) but its update is irregular. Therefore, the report does not provide any graphic tool to keep track of demand changes on a daily basis.

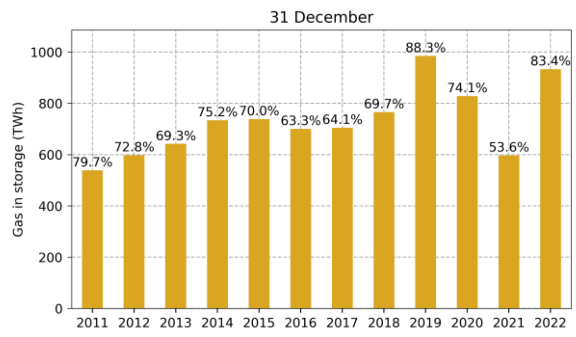
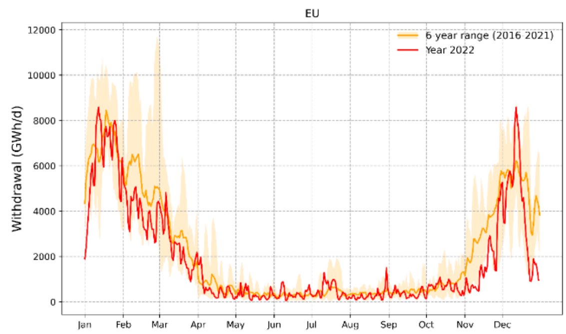
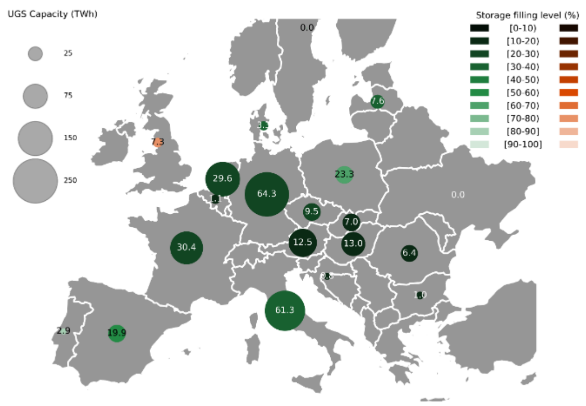
6.1 Monitoring the operation of underground gas storage facilities

Table 7 shows a list of graphic tools to monitor the operation of UGS facilities in the EU or aggregated per MS. For quick reference, the table shows the visual aid, its reference in the document, and a short description. In Figure 4, the reference period could be adapted to reflect better the emphasis of the evolution of the storage trajectory or to shrink it to the most recent years. Figure 8 is just an example of the monitoring of the storage withdrawal at EU level that can be changed to keep track of the storage injection or the net storage injection (difference between injection and withdrawal).

In subsections 6.1.1 and 6.1.2, storage projections and equivalent days of Reference Winter consumption are additional proposed metrics to monitor the security of gas supply in the EU.

Table 7. Monitoring tools for the daily operation of underground gas storage facilities.

<table>
<tr><th>Figure</th><th>Reference</th><th>Description</th></tr>
<tr><td>
</td><td>Figure 2</td><td>Evolution of the EU gas filling level compared to the trajectories of previous years</td></tr>
<tr><td>
</td><td>Figure 4</td><td>Evolution of the EU gas filling level compared to the average and range of a reference period</td></tr>
</table>

	Figure 5	EU gas in storage level in absolute and relative terms in the same day for all years
	Figure 8	EU gas withdrawal from gas storages compared to the average and range of a reference period
	Figure 10	Gas in storage and filling level for underground gas storages in the EU Member States, United Kingdom and Ukraine

Source: JRC based on AGSI+ Transparency Platform, 2023.

6.1.1 Underground gas storage projections

Storage projections are useful to estimate the gas in storage level on a certain day in the near future. These projections can be derived from modelling simulations or forecasting techniques, however this would require running simulations on a daily basis while relying heavily on extra information to set up simulations or forecasts. We opted for a simplified approach and derived them based on historical withdrawal and injection behaviour. As an example, these projections were used in Fernández-Blanco Carramolino et al. (2023) to determine whether a country may find it difficult to meet the intermediate filling targets outlined in the Gas Storage Regulation (Fernández-Blanco Carramolino, Rodríguez-Gómez, & Bolado-Lavín, 2023).

Figure 39 shows two projected EU filling level trajectories since 10 January 2023 until the end of the winter 2022-2023 without resorting to modelling simulations or forecasting techniques. This is used to create awareness about the potential storage level to be achieved at the end of the winter 2022-2023. The assumptions for deriving these storage projections are as follows:

— Initial date: 10 January 2023. This is the start of the projected trajectory, and the filling level is known and equal to 82.6%.

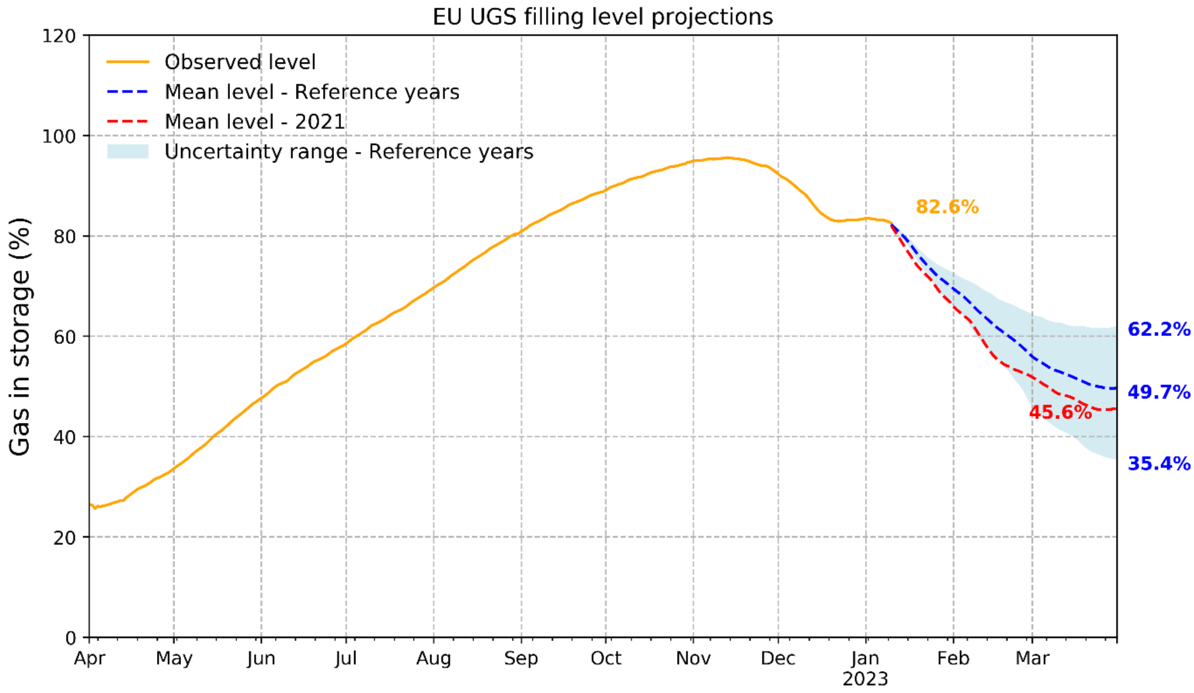
— End date: 31 March 2023. The projection could be extended further in time, but the research question is limited to winter 2022-2023.

— Storage capacity curves for injection and withdrawal, which account for the relationship between the current storage volume and the maximum injection/withdrawal capacity, are considered.

— The projected trajectory in blue assumes average, minimum and maximum values of net injections during the reference years 2016-2018, while the projected trajectory in red assumes the net injections during 2021. The latter period is characterised for its higher withdrawals compared to the reference years.

The average EU filling level is projected at around 50% on 31 March 2023 by assuming average net injections of years 2016-2018 (blue line). By assuming higher net withdrawals, the EU filling level is projected at 46% (red line). The first projection computes also an uncertainty range leading to pessimistic and optimistic estimates. The longer the period is projected during winter, the higher the uncertainty range. In this case, the extreme projected levels are 35% and 62%.

Figure 39. Underground gas storage trajectory projection in the European Union from 10 January 2023 until 31 March 2023, assuming a reference period of 2016-2018 (blue) and of 2021 (red). An uncertainty range is shown in light blue.



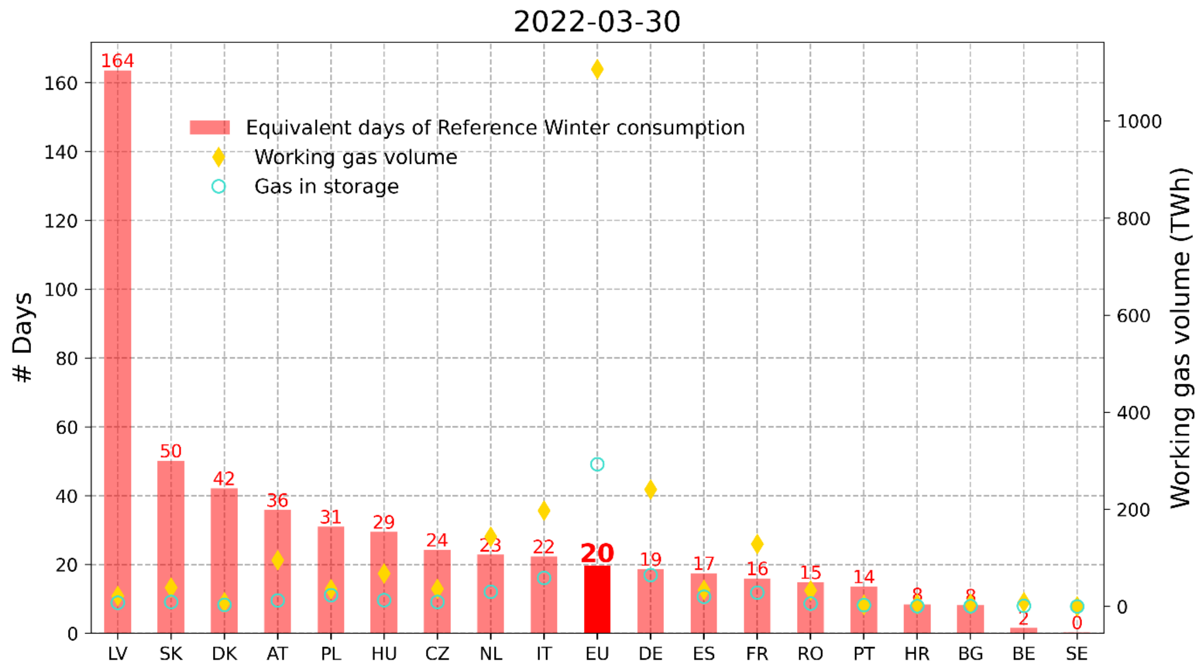
Source: JRC based on AGSI+ Transparency Platform, 2023.

6.1.2 Equivalent days of Reference Winter consumption

In the context of gas storages, the equivalent days of *Reference Winter consumption* are defined as the number of days of Reference Winter consumption that are stored in the aggregated gas storage facilities. In this definition, the technical limitations of underground gas storages, such as the injectability/deliverability capacity curves, are ignored. This metric is thus obtained by dividing the gas in storage level on a certain day by the corresponding average reference winter consumption. The latter value comes from the ENTSOG Winter Supply Outlook 2022 (ENTSOG, 2022) and it is provided for each Member State. To compute the equivalent days of reference winter consumption at EU level, the aggregated gas in storage level is divided by the sum of the country-specific average reference winter demand in the EU.

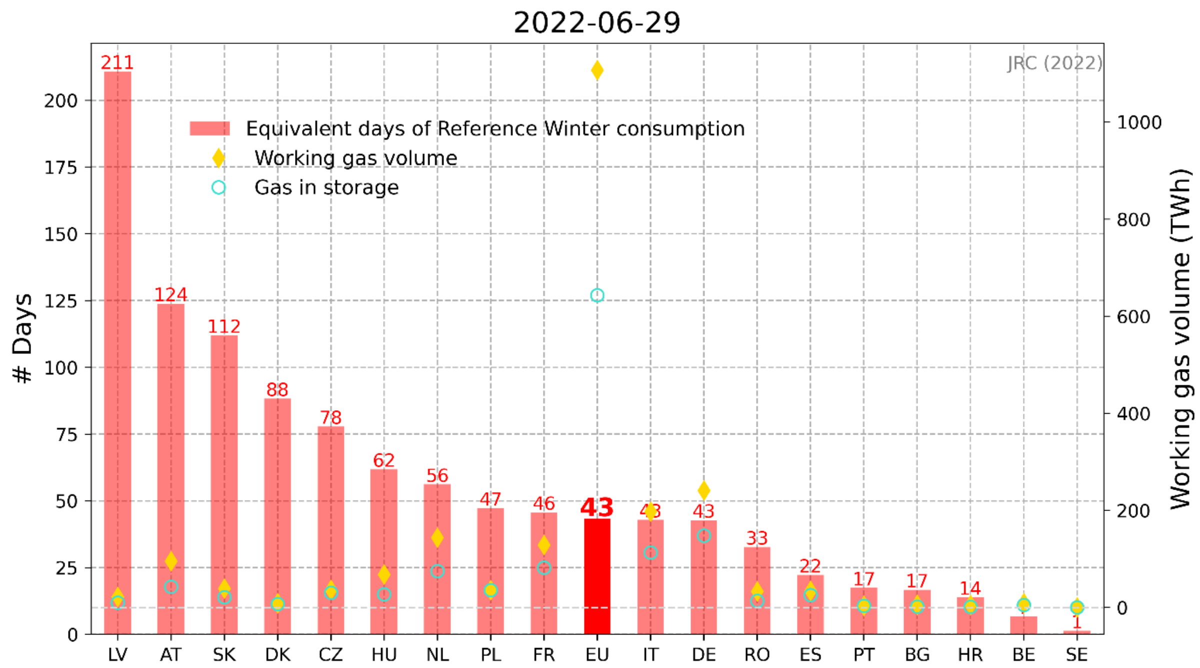
Figure 40 and Figure 41 show two examples of the equivalent days of Reference Winter consumption by country and at EU level. The former figure shows the metric for the inventory level on 30 March 2022, i.e., at the end of the winter when the storages are more depleted. The latter figure shows it on 29 June 2022, i.e., in the middle of the summer when storages are refilled to face the next winter.

Figure 40. Equivalent days of Reference Winter consumption on 30 March 2022.



Source: JRC based on AGSI+ Transparency Platform and ENTSOG, 2023.

Figure 41. Equivalent days of Reference Winter consumption on 29 June 2022.

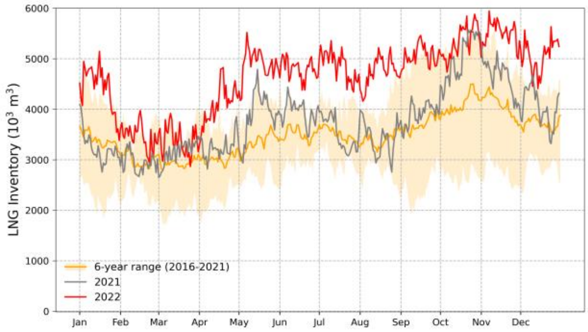
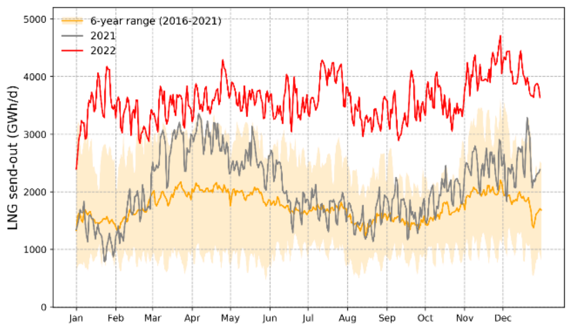
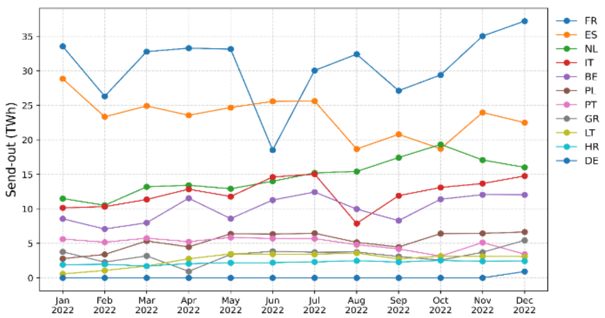


Source: JRC based on AGSI+ Transparency Platform and ENTSOG, 2023.

6.2 Monitoring the operation of liquefied natural gas facilities

Table 8 shows a list of graphic tools to monitor the operation of LNG facilities in the EU or aggregated per MS. For quick reference, the table shows the visual aid, its reference in the document, and a short description. Figure 21 shows the LNG send-out flows for the EU MSs with LNG facilities at monthly granularity. When looking at this figure on a daily basis, the last month would show the accumulated daily LNG send-out flow.

Table 8. Monitoring tools for the daily operation of liquefied natural gas facilities.

Figure	Reference	Description
	Figure 16	LNG inventory at EU level compared to the average and range of a reference period
	Figure 17	LNG send-out flow at EU level compared to the average and range of a reference period
	Figure 21	LNG send-out flow by EU Member State per month

Source: JRC based on ALSI Transparency Platform, 2023.

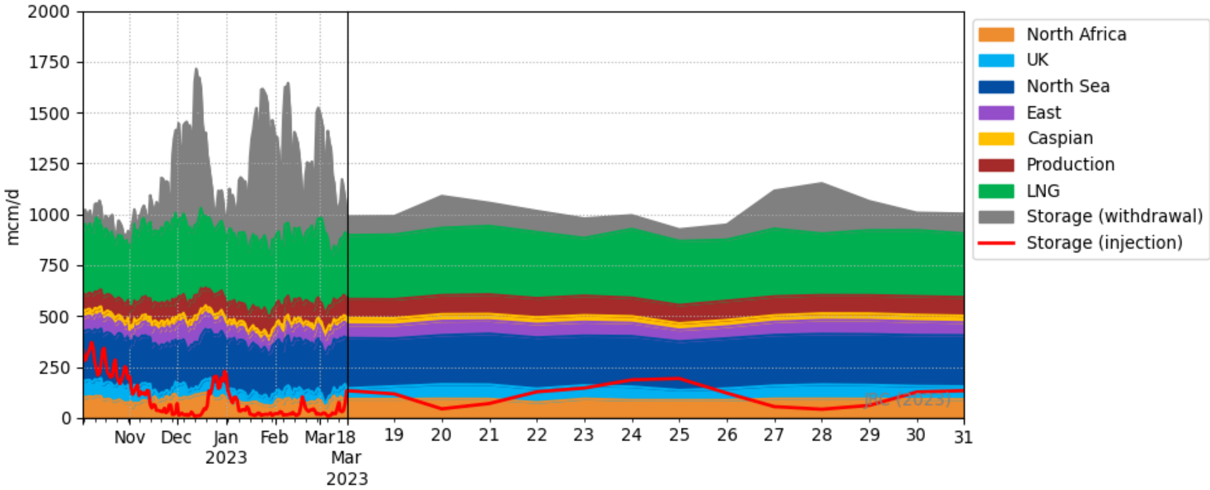
6.3 Monitoring the natural gas supply

Transport data is fundamental to monitor the security of gas supply of the European Union and the ENTSOG Transparency Platform facilitates this task by providing publicly such data in real time. This allows to investigate the causes and potential impacts of supply reduction throughout a corridor or a route. Sometimes the monitoring task is challenging given the amount of information that needs to be processed and subsequently analysed.

Figure 42 and Figure 43 present the natural gas supply status in a daily and weekly granularity in mcm/d ([43]). The figures show the gas inflow via pipelines and LNG send-out, as well as storage withdrawal, compared with the storage injection, which is useful to monitor the gas supply on a daily or weekly basis, with a one- or two-day delay. The status on 31 March 2023 demonstrates the reduction in storage withdrawal and the increase in storage injection at the end of the gas winter. This format also shows any large decrease in import flow according to the import corridors (North Africa, UK, North Sea, East, and Caspian). Figure 43 additionally highlights the pipeline utilisation routes over a certain week, showing their unused potential.

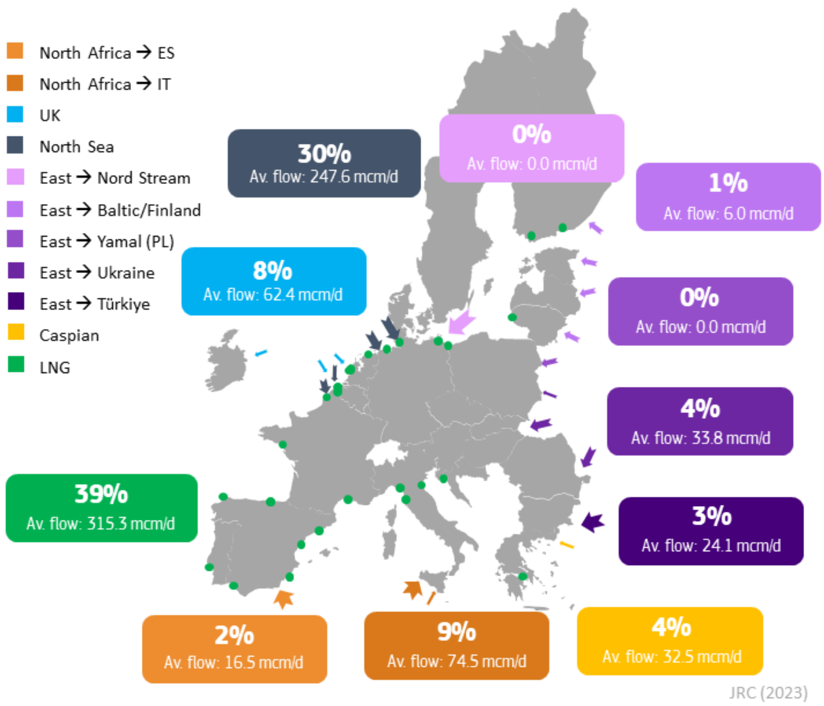
([43]) A uniform GCV of 11.2 kWh/Nm^3 is used to transform energy units into volumetric ones.

Figure 42. Six-month overview of the natural gas supply in the EU until 31 March 2023. Inflow along pipeline corridors, LNG send-out and storage withdrawal, compared to storage injection (mcm/d).



Source: JRC based on ENTSOG, AGSI+, and ALSI Transparency Platforms, 2023.

Figure 43. Average firm capacity utilisation (%), natural gas imports, LNG send-out, storage withdrawal, and domestic gas production (mcm/d) during the week of 25-31 March 2023.



Source: JRC based on ENTSOG, AGSI+, and ALSI Transparency Platforms, 2023.

7 Conclusions

This report analysis the performance of the natural gas system of the European Union in 2022 compared to historical years and encompasses a set of daily monitoring tools to keep track of the latest changes in its operation. The Joint Research Centre (JRC) has closely monitored the evolution of the operation of the natural gas system, including underground gas storages and LNG regasification terminals, using publicly available data platforms such as ENTSOG Transparency Platform (TP) for transport data, AGSI+ TP for gas storages, and ALSI TP for LNG facilities. Other databases such as Eurostat and ENaGaD were also used to a lesser extent for gas consumption information. Thanks to this work, we provided a continuous policy support to DG ENER in response to the energy crisis started in the second half of 2021.

It is worth mentioning that a python module was implemented to download and analyse transport data such as internal physical flows or flows with non-European Union countries in a more efficient manner. Unlike gas storage and LNG TPs, transport data is more complex to analyse given the data heterogeneity of the ENTSOG data platform and the number of reported interconnection points, which is by far higher than the number of gas storage facilities and LNG terminals reported by ASGI+ and ALSI TPs. A description of this tool is beyond the scope of this report and can be found in (Jung, et al., 2022).

Some key facts that describe the performance of the EU natural gas system operation in 2022 are as follows:

— EU gas storages started 2022 with 54% of filling level, almost 18 percentage points below the 6-year average. The filling level at the end of the winter 2021-2022 remained at the 2016-2018 average (around 26%). Maximum storage filling level was reached on 13 November 2022 (95.7%). Similar high levels were observed only in the year 2019. Unlike previous years, there was a slightly increase in the gas in storage in the EU at the end of 2022, reaching 83% on 31 December 2022.

— EU net injections in summer 2022 (692 TWh) were 33% higher than the 11-year average and 18% higher than the 6-year average. In addition, extractions during winter were moderate (around 540 TWh), just 9% lower than the 6-year average.

— The filling levels across EU Member States were more homogeneous in 2022 than in 2021, especially on 1 November. This is explained by the minimum storage obligations imposed by the Gas Storage Regulation.

— Gazprom storage sites reached its minimum in April 2021 (16.5%) which represented half of the EU filling level. However, policy-driven decisions allowed to refill these storages during the 2022 injection season, thus following the same trend observed at EU level.

— The aggregated LNG in the EU has been characterised by high levels in inventory and high send-out flows for most of the days in 2022. The EU LNG storage levels were 24% higher than in 2021 and 33% higher than the 6-year average. Regarding the LNG send-out flows, the annual LNG flow increased dramatically by 73% compared to 2021 (1315 TWh versus 761 TWh in 2021), and doubled the average of the past 6 years.

— France, Spain, Netherlands and Italy comprised 74% of the annual LNG send-out flow of the EU in 2022. Overall, all countries with access to LNG terminals increased dramatically their annual LNG utilisation factors compared to 2021 except in Portugal wherein its utilisation factor was already above 80% in 2021.

— Gas import via pipelines suffered a significant decrease in the period between 2020 and 2022, due to the drop in flows along the Eastern corridor. In summer 2022, flow along the Yamal and Baltic + Finland routes stopped, and imports from Ukraine and Nord Stream decreased from a total share of 38% (winter 2020-2021) to 20%. These changes led to a drop of imports via pipelines of 36% between gas winter 2020-2021 and 2022-2023, partially counterbalanced via increased flows along North Sea and United Kingdom routes, and via LNG.

— Between 2021 and 2022, intra-EU flow saw an increase of capacity utilisation and the introduction of new and reversed flow directions. Nevertheless, median utilization remains mostly below 100% (except for interconnections between Belgium and Germany, Belgium and the Netherlands, and France and Belgium). The highest median utilization (2.43) is reached in the cross-border interconnection Belgium-Germany in summer 2022, when LNG send-out and imports from United Kingdom significantly decreased.

— The gas consumption has decreased by 11% in 2022 in the European Union. This reduction has been motivated by the mild winters 2021-2022 and 2022-2023 and the political action towards a voluntary demand reduction of 15% since 1 August 2022 until 31 March 2023.

Regarding the monitoring of the operation of the natural gas system of the European Union, we highlight the following concluding remarks:

— Effective monitoring of the natural gas system relies on the transmission system operators for gas, storage system operators, and LNG system operators, which are in charge to voluntarily feed the precious databases on a daily basis. The data come with a two-day delay only in the worst-case scenarios, which helps perform a real-time monitoring of the natural gas system operation, thus proving the adequacy of the current data sources in times of crisis.

— Promotion of data sharing is essential to support policy makers under exceptional circumstances and feed researchers with high quality data that can be used for modelling exercises (analysis of disruption scenarios or assessment of investment decisions).

— We provide a suite of plots that can be used to monitor the gas sector on a daily and weekly basis.

— Storage projections at European or national levels can be estimated based on historical values and the injection/withdrawal capacity curves. These projections could be a proxy for the ones resulting from modelling simulations which are more time consuming.

Further work will be devoted to the development of a dashboard for monitoring the security of gas supply in a dynamic way by offering flexibility to the analyst. Another interesting avenue of research is the real-time monitoring of the natural gas consumption per country and aggregated at European Union level. The ENaGaD database may be a powerful tool to estimate and monitor the gas consumption reduction with a higher granularity than Eurostat despite the small differences encountered between both data sources.

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List of abbreviations and definitions

ACER	Agency for the Cooperation of Energy Regulators
AGSI	Aggregated gas storage inventory
ALSI	Aggregated LNG storage inventory
API	Application Programming Interface
AT	Austria
BE	Belgium
BG	Bulgaria
CZ	Czechia
DE	Germany
DK	Denmark
DG-ENER	Directorate-General for Energy
EC	European Commission
ENaGaD	The European Natural Gas Demand database
ENTSOG	European Network of Transmission System Operators for Gas
ES	Spain
EU	European Union
FR	France
GCV	Gross calorific value
GIE	Gas Infrastructure Europe
GME	Gaz Maghreb Europe pipeline
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IEA	International Energy Agency
IGA	Inter-Governmental Agreements
IT	Italy
JRC	Joint Research Centre
LNG	Liquefied natural gas
LSO	LNG Storage Operator
LV	Latvia
MS	Member State
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
RS	Serbia
RU	Russia

SE	Sweden
SI	Slovenia
SK	Slovakia
SSO	Storage System Operator
TP	Transparency Platform
TSO	Transmission System Operator
UA	Ukraine
UK	United Kingdom
UGS	Underground Gas Storage

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Annexes

Annex 1. Underground gas storage data

Table 9 shows the gas in storage in TWh for all EU countries on three key days (1 April, 1 November and 1 December) for the years 2021 and 2022. This table also provides the corresponding relative change in gas stored in 2022 with respect to the one in 2021. The corresponding storage filling levels are listed in Table 10.

Table 9. Gas in storage in TWh at both country and EU levels on three key days (1 April, 1 November, and 31 December) and years 2021-2022 as well as its relative change in 2022 compared to the values in 2021.

Country code	1 Apr. 2021	1 Apr. 2022	Relative diff. on 1 Apr. (%)	1 Nov. 2021	1 Nov. 2022	Relative diff. on 1 Nov. (%)	31 Dec. 2021	31 Dec. 2022	Relative diff. on 31 Dec. (%)
AT	23.7	12.5	-47.2	53.6	88.9	66.1	33.1	83.6	153.0
BE	2.2	1.1	-47.2	8.3	9.0	8.0	5.4	6.7	23.0
BG	0.8	1.0	28.1	4.3	5.2	21.0	2.8	4.8	69.7
HR	1.0	0.9	-17.9	4.3	4.6	8.4	3.0	4.4	47.4
CZ	10.2	9.5	-7.0	31.0	41.5	33.8	20.5	37.7	84.0
DK	3.7	3.3	-10.6	7.4	9.2	24.1	6.5	9.0	39.4
FR	28.5	30.4	6.8	121.5	132.8	9.3	74.6	112.6	50.9
DE	66.5	64.3	-3.4	174.1	243.3	39.7	128.5	221.7	72.5
HU	34.3	13.0	-62.0	51.8	58.0	12.0	33.1	47.6	43.8
IT	72.7	61.3	-15.7	173.2	184.6	6.6	129.4	159.5	23.2
LV	5.6	7.6	36.8	17.1	13.9	-18.8	12.1	11.3	-6.6
NL	32.6	29.6	-9.2	88.5	127.6	44.1	51.4	107.2	108.4
PL	13.7	23.3	70.2	34.6	36.0	4.2	30.2	35.2	16.4
PT	2.1	2.9	36.3	2.4	3.9	60.1	2.9	3.9	35.1
RO	5.7	6.4	12.8	24.5	31.7	29.3	17.4	26.3	51.1
SE	0.0069	0.0069	0.0	0.0069	0.0941	1263.8	0.0069	0.0885	1182.6
SK	18.1	7.0	-61.4	27.4	35.5	29.3	17.8	28.5	59.7
ES	20.5	19.9	-2.9	28.3	33.4	18.1	22.6	32.9	45.7
EU	342.7	293.2	-14.5	859.0	1060.1	23.4	597.2	933.3	56.3

Source: JRC based on AGSI+ Transparency Platform, 2023.

Table 10. Storage filling level in percentage at both country and EU levels on three key days (1 April, 1 November, and 31 December) and years 2021-2022.

Country code	1 Apr. 2021	1 Apr. 2022	1 Nov. 2021	1 Nov. 2022	31 Dec. 2021	31 Dec. 2022
AT	24.8	13.1	56.1	93.1	34.6	87.2
BE	24.1	12.7	92.5	100.0	60.5	88.0
BG	12.3	17.0	74.6	90.4	48.3	82.2
HR	19.9	17.9	81.9	97.0	56.7	91.4
CZ	28.4	26.4	86.3	94.9	57.0	86.2
DK	35.2	36.3	81.9	99.3	71.3	90.7
FR	22.2	23.3	94.6	100.0	58.1	84.3
DE	27.8	26.7	72.3	99.2	53.3	90.1
HU	49.1	19.3	76.5	85.7	49.0	70.4
IT	36.8	31.0	87.6	95.5	65.5	82.5
LV	25.9	35.0	78.5	57.7	55.6	47.1
NL	22.6	20.3	61.6	91.8	35.8	77.1

PL	38.2	65.0	96.6	98.9	84.4	96.6
PT	58.7	80.1	68.2	100.0	80.8	98.3
RO	17.3	19.5	74.4	96.8	52.7	80.2
SE	8.0	66.6	66.4	92.9	66.4	87.3
SK	42.6	19.4	70.8	91.3	46.0	73.3
ES	59.9	56.5	82.6	94.8	65.9	93.3
EU	30.6	26.5	77.1	95.0	53.6	83.4

Source: JRC based on AGSI+ Transparency Platform, 2023.

Annex 2. Liquefied natural gas data

This annex provides the tables related to the operation of the LNG facilities in the European Union. Table 11 shows the monthly and annual LNG send-out flows and corresponding utilisation factors in 2022, 2021, and the average of the last six years (2016-2021). Table 12 summarises the average LNG stocks per month and year. Table 13 shows the maximum LNG send-out utilisation observed from 2016 until 2021 and 2022 by EU Member State and aggregated at EU level. This table also provides the relative increase of the maximum send-out flow in 2022 compared to the one in 2021. Likewise, Table 14 shows the maximum send-out flow per LNG terminal observed from 2016 until 2021 and 2022. Note that, to ensure that the values do not exceed the regasification capacity in both Table 13 and Table 14, the maximum LNG send-out flow is calculated as the 99th percentile of the corresponding time series.

Table 11. Monthly and annual LNG send-out flow and utilisation factor in the European Union.

Period	Send-out flow (TWh)			Utilisation factor (%)		
	6-year average	2021	2022	6-year average	2021	2022
January	47.4	40.5	107.3	29.2	23.7	62.1
February	45.3	45.7	91.4	30.6	29.6	58.6
March	60.5	84.3	107.9	37.1	49.3	62.4
April	61.5	88.8	110.1	38.8	53.7	65.6
May	60.4	77.5	112.4	36.8	45.3	64.5
June	51.7	61.4	105.5	32.6	37.1	62.1
July	53.0	54.3	119.9	32.3	31.7	68.2
August	45.9	47.4	104.1	27.8	27.7	59.2
September	44.6	51.0	102.3	28.0	30.8	58.9
October	50.7	60.2	109.7	30.9	35.2	59.8
November	59.9	73.8	122.6	37.6	44.6	68.7
December	55.9	76.0	123.0	33.7	44.4	65.8
Annual	636.7	760.8	1316.2	32.9	37.8	63.0

Source: JRC based on ALSI Transparency Platform, 2023.

Table 12. Monthly and annual average LNG inventory in the European Union in 10^3 m^3 LNG.

Period	6-year average	2021	2022
January	3398.6	3240.4	4427.5
February	2999.3	2945.6	3471.1
March	2938.4	3129.0	3388.8
April	3021.2	3252.1	4051.0
May	3346.5	3873.3	4876.9
June	3504.2	3943.2	4797.6
July	3506.2	3537.2	4872.3
August	3398.6	3426.4	4742.2
September	3707.2	3899.0	5043.4
October	4104.6	4959.7	5336.2
November	4085.8	4706.3	5500.4
December	3717.5	4052.0	5144.5
Annual	3477.3	3747.0	4637.7

Source: JRC based on ALSI Transparency Platform, 2023.

Table 13. Maximum LNG send-out flow and regasification capacity per Member State and aggregated at EU level at the end of 2021 and 2022.

Country code	Up to 31 December 2021		Up to 31 December 2022		Increase of max send-out in 2022 (%)
	Max send-out (GWh/d)	Capacity on 31 Dec. 2021 (GWh/d)	Max send-out (GWh/d)	Capacity on 31 Dec. 2022 (GWh/d)	
BE	408.7	541.0	466.3	541.0	14.1
DE	0.0	0.0	0.0	163.5	-
ES	929.7	1910.4	1080.2	1910.4	16.2
FR	1076.9	1252.7	1234.7	1277.7	14.7
GR	167.1	269.9	173.2	269.9	3.7
HR	69.3	79.9	85.3	85.5	23.2
IT	523.1	514.5	534.0	560.2	2.1
LT	101.5	122.4	117.6	122.4	15.9
NL	423.5	461.0	680.6	762.9	60.7
PL	162.3	220.0	220.0	220.0	35.6
PT	210.9	200.0	210.6	200.0	-0.1
EU	3244.5	5571.8	4204.8	6113.5	29.6

Source: JRC based on ALSI Transparency Platform, 2023.

Table 14. Maximum LNG send-out flow and regasification capacity per LNG facility at the end of 2021 and 2022.

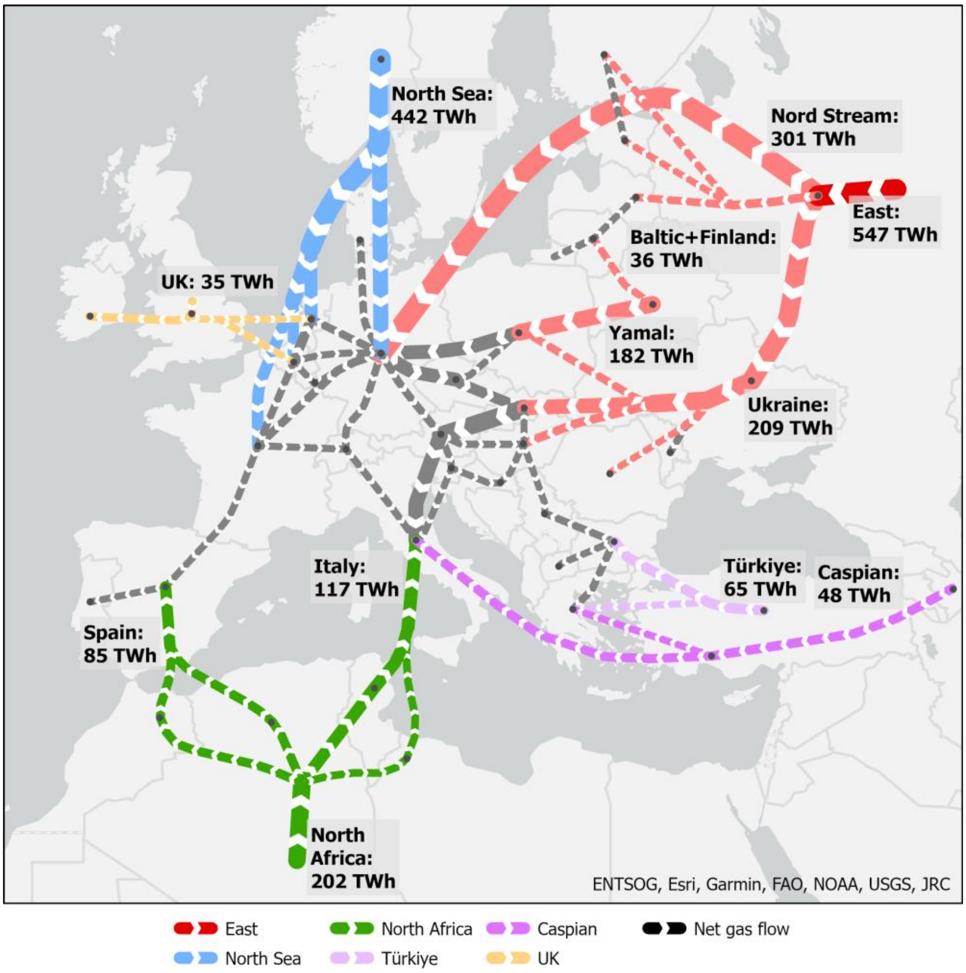
Country	Terminal	Up to 31 December 2021		Up to 31 December 2022		Increase of max send-out in 2022 (%)
		Max send-out (GWh/d)	Capacity on 31 Dec. 2021 (GWh/d)	Max send-out (GWh/d)	Capacity on 31 Dec. 2022 (GWh/d)	
BE	Zeebrugge	408.7	541	466.3	541	14.1
HR	Krk (FSRU)	77.4	79.9	85.4	85.5	10.3
FR	Fos Tonkin	125.8	95.9	125.3	95.9	-0.4
	Montoir de Bretagne	407.1	337	405.9	337	-0.3
	Dunkerque	436.4	519.8	496.6	544.8	13.8
	Fos Cavaou	312.6	300	373.0	300	19.3
DE	Wilhelmshaven 1 (FSRU)	0.0	0	0.0	163.5	-
GR	Revythoussa	167.1	269.9	173.2	269.9	3.7
IT	Panigaglia	121.4	119.5	121.4	119.5	0.0
	FSRU OLT Offshore Toscana	155.3	166.5	155.1	166.5	-0.1
	Rovigo	287.4	228.5	286.6	274.3	-0.3
LT	FSRU Independence	102.0	122.4	117.6	122.4	15.3
NL	EemsEnergy	0.0	0	191.5	249.6	-
	Rotterdam Gate	423.5	461	499.4	513.3	17.9
PL	**Świnoujście**	162.3	220	220.0	220	35.6
PT	Sines	210.9	200	210.6	200	-0.1
ES	Bilbao	248.3	222.7	247.8	222.7	-0.2
	Barcelona	269.6	542.9	278.7	542.9	3.4
	Huelva	267.0	375.8	286.0	375.8	7.1
	Cartagena	184.4	375.8	241.5	375.8	30.9
	Sagunto	197.7	278.3	225.3	278.3	14.0
	Mugardos	114.9	114.9	114.8	114.9	-0.1

Source: JRC based on ALSI Transparency Platform, 2023.

Annex 3. Natural gas imports from main corridors

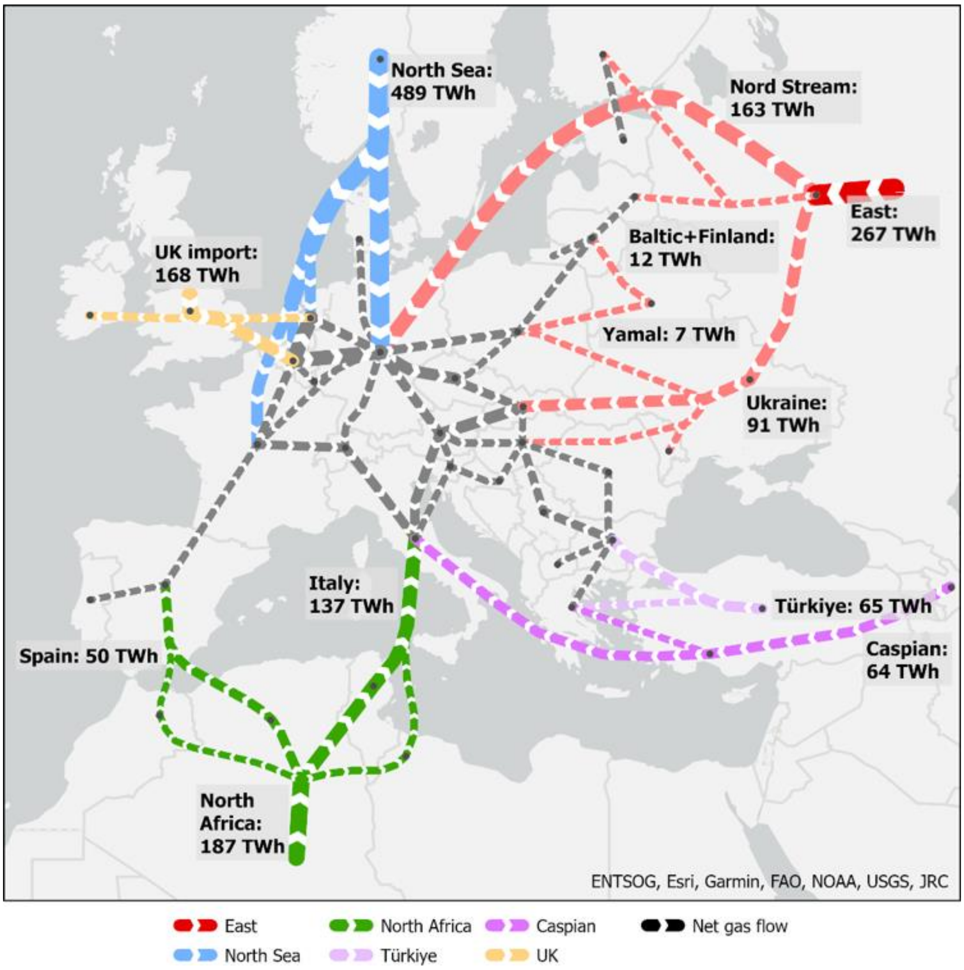
Figure 44-Figure 48 provide an overview of the natural gas flows in the EU, as well as the imports from non-EU countries, for each gas season between October 2020 and March 2023.

Figure 44. Natural gas imports to the European Union from main corridors and routes in gas summer 2021 (1 April 2021 – 30 September 2021). Import routes are characterized by different colours, and flow magnitude and direction are represented by the size and direction of the arrows.



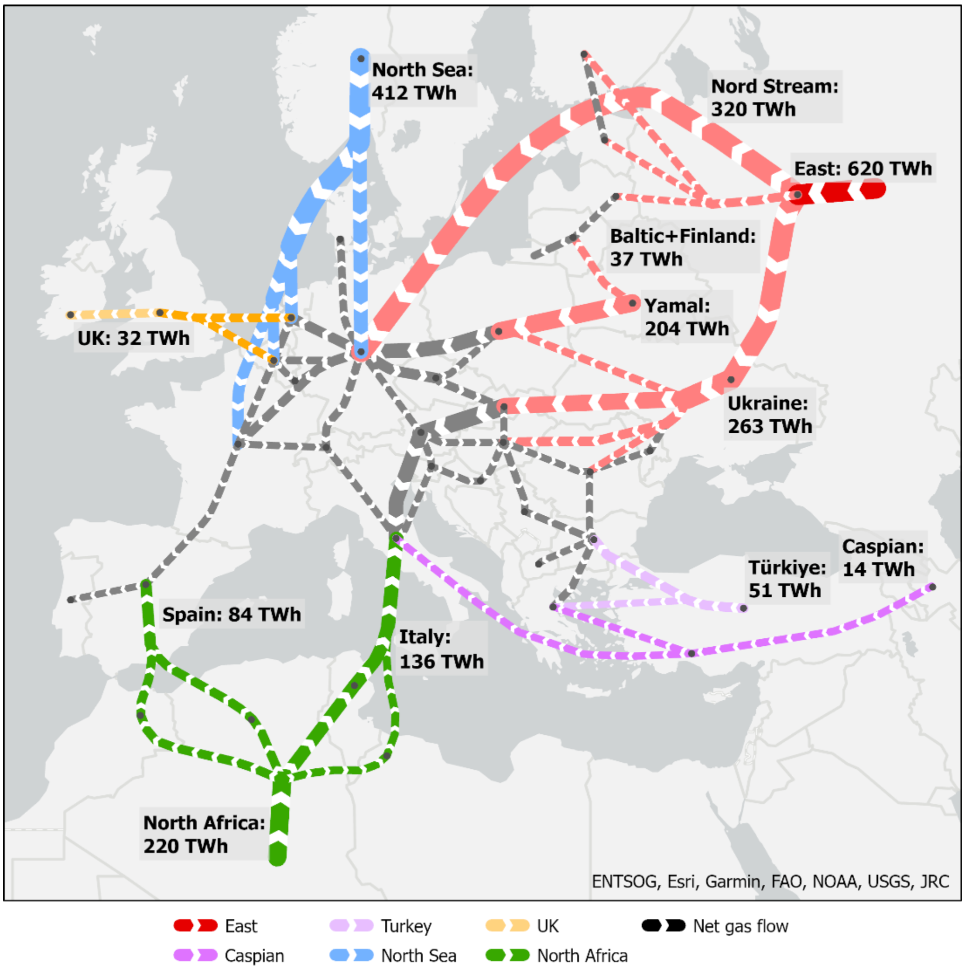
Source: JRC based on ENTSOG Transparency Platform, 2023.

Figure 45. Natural gas imports to the European Union from main corridors and routes in gas summer 2022 (1 April 2022 – 30 September 2022). Import routes are characterized by different colours, and flow magnitude and direction are represented by the size and direction of the arrows.



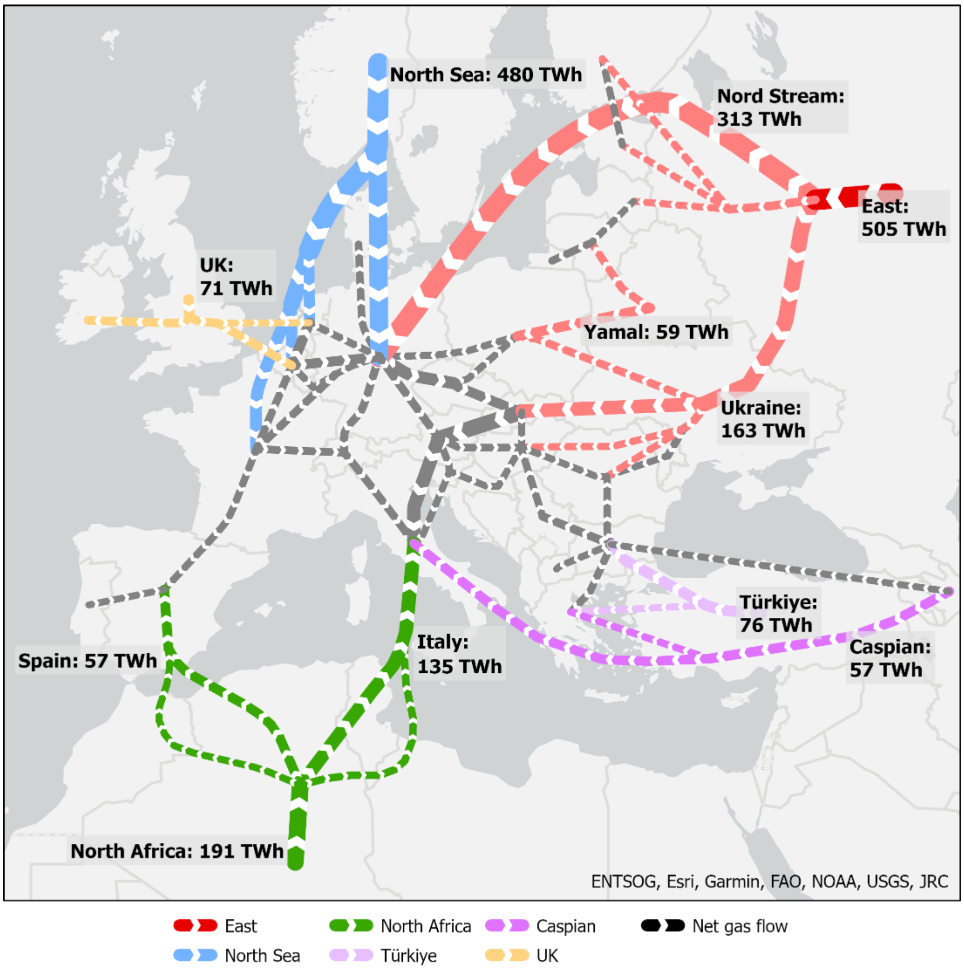
Source: JRC based on ENTSOG Transparency Platform, 2023.

Figure 46. Natural gas imports to the European Union from main corridors and routes in gas winter 2020-2021 (1 October 2020 – 31 March 2021). Import routes are characterized by different colours, and flow magnitude and direction are represented by the size and direction of the arrows.



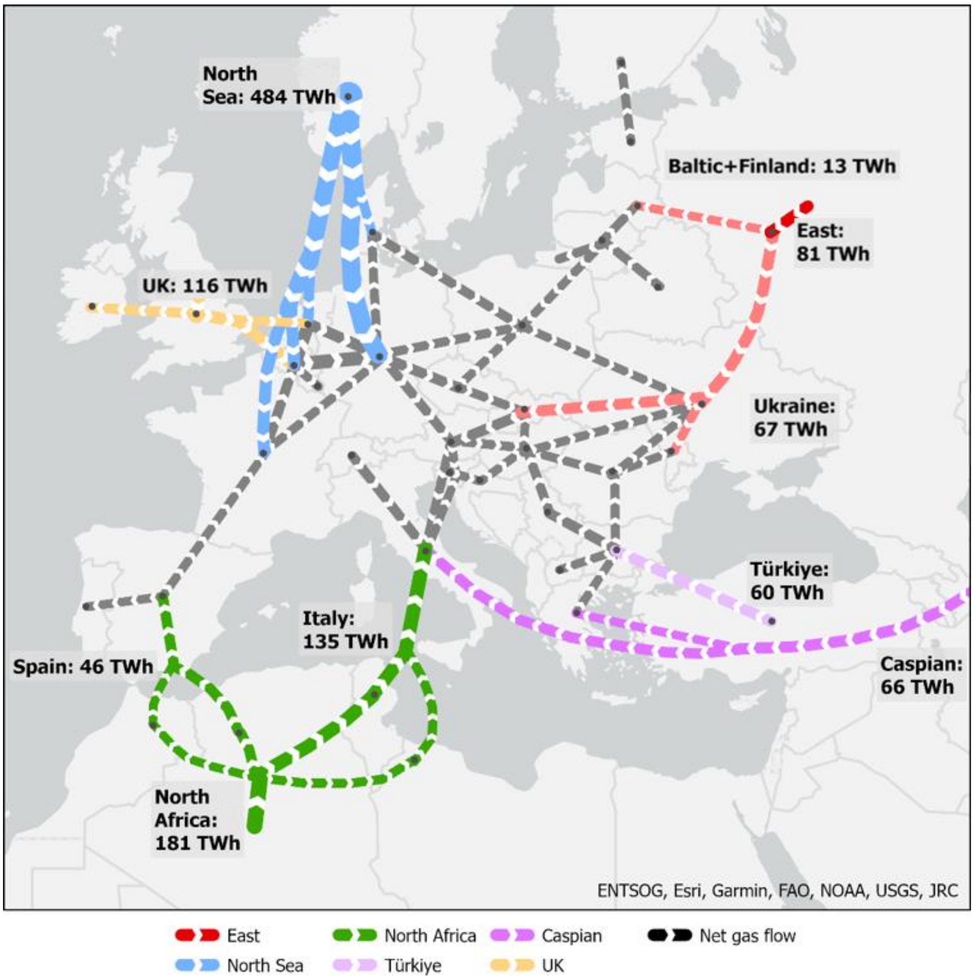
Source: JRC based on ENTSOG Transparency Platform, 2023.

Figure 47. Natural gas imports to the European Union from main corridors and routes in gas winter 2021-2022 (1 October 2021 – 31 March 2022). Import routes are characterized by different colours, and flow magnitude and direction are represented by the size and direction of the arrows.



Source: JRC based on ENTSOG Transparency Platform, 2023.

Figure 48. Natural gas imports to the European Union from main corridors and routes in gas winter 2022-2023 (1 October 2022 – 31 March 2023). Import routes are characterized by different colours, and flow magnitude and direction are represented by the size and direction of the arrows.



Source: JRC based on ENTSOG Transparency Platform, 2023.

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