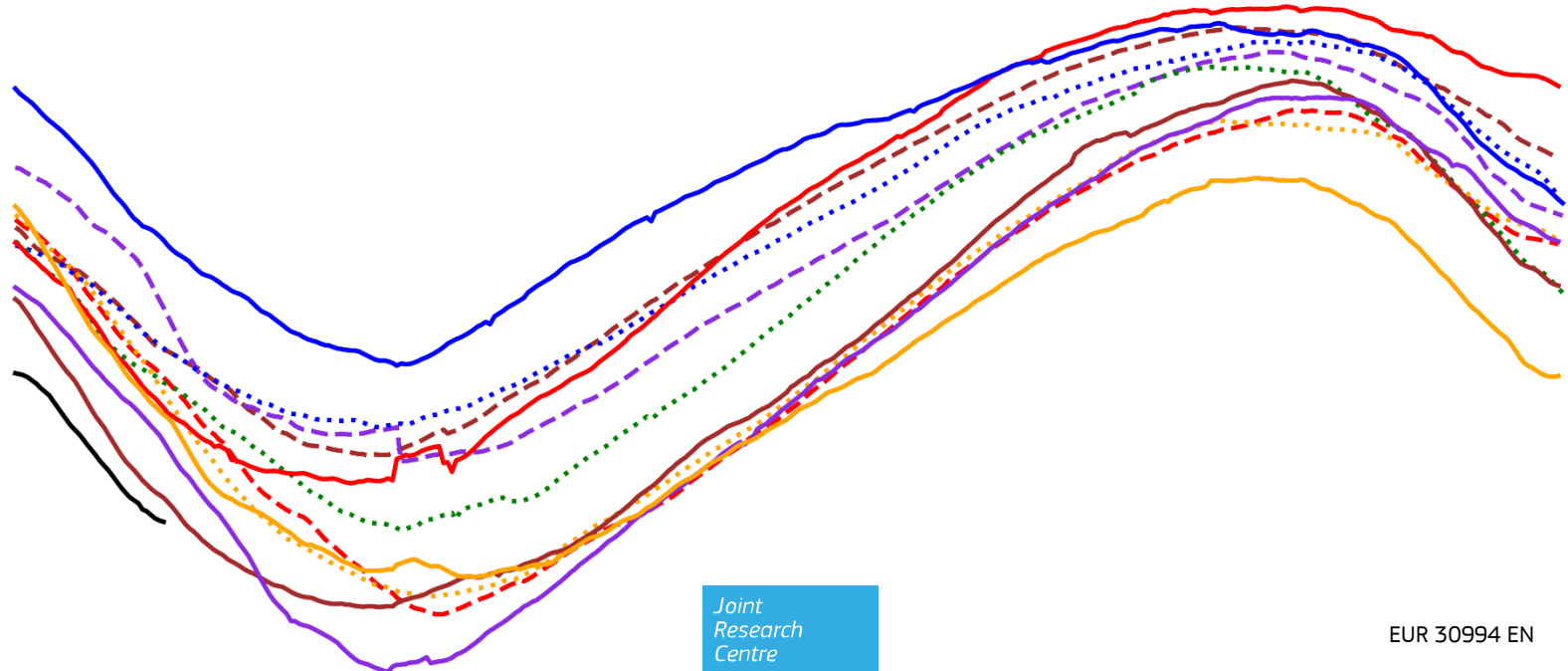# JRC TECHNICAL REPORT

Impact of storage obligations on the EU gas market

An analysis with METIS

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Extended abstract

Due to the sustained and persistent increase in gas prices observed in the last months of 2021, the Directorate-General for Energy (DG ENER) has requested the Joint Research Centre (JRC) to simulate the current short-term gas market using the gas module of the METIS software. The goal of these quantitative model-based analyses is to derive economic insights at European Union (EU) level and explore some policy options. This report is part of a wider analysis of this subject which also includes the impact of gas prices on the electricity system and feedback effects between these two sectors.

Evaluation question

This work has been triggered by two evaluation questions:

— How does the filling level trajectory of seasonal EU underground gas storages drive gas prices in autumn and winter?

— Would the establishment of minimum gas storage volumes at the beginning of winter have led to lower gas prices during September to November of 2021? How would the situation compare across Member States (MSs)?

Methodology

A METIS "current context 2021" ([1]) has been built to represent the technical and economic constraints of the EU gas system and market. This context is run for one calendar year in daily time steps for a reference scenario based on current data and compared with two simulated policy options. The factual or reference scenario reproduces the observed gas system/market until October 2021. For the last three months of the year, we simulate three levels of scarcity driven by EU gas demand and availability of extra EU supplies, which are referred to as "pessimistic", "base", and "optimistic" test cases. For the same time span, we simulate the impact of policy measures. The assessed impacts of the policies are quantified by the differences in identified outcome variables in the presence and in absence of policy measures.

The main outcome variables are the economic and technical indicators: (i) gas prices; (ii) social welfare; (iii) total system cost; and (iv) storage gas level throughout the year.

Assumption of the storage boundary condition

For all scenario runs, the level of gas in storages at the end of the calendar year is maintained above or equal to a threshold value. This threshold is, in principle, a safe minimum storage level ensuring excessive depletion (i.e. to ensure availability and affordability of gas in subsequent seasons). To determine this parameter for our simulations we refer to historical data. In the figure below the yellow line shows the observed trend for gas in storage in the year 2021, while the blue dashed line and the blue shaded area are projections derived from the minimum, average, and maximum withdrawal observed in the corresponding period of the season from the last six winters. In this figure, we can observe that the average storage filling level at the end of the year is around 55%, which is 15 percentage points below the mean storage filling level at that specific time from the reference period 2016-2018. Trajectories that fall below this level on 31 December 2021 may not guarantee security of supply during the rest of the gas year ([2]). This 55% at EU level is not applied uniformly on each MS, but each MS with storage has a corresponding threshold that varies across countries and it is derived based on the average filling level from the reference period 2016-2018.

([1]) A "context" in the METIS model describes an energy scenario modelled in METIS. A context includes all input data (list of modelled countries, asset parameters, time series …) for a given year but also the simulation results once the simulation is done. Running sensitivity runs on a given scenario would result in different METIS contexts, reflecting the same scenario, but with varying parameter values and results.

([2]) "Gas year" refers to the period of 365 (or 366) days from 1 October at 6:00 until 30 September at 6:00 of the year after.

Definition of counterfactual gas storage scenarios

Two counterfactual scenarios are described as follows:

— A first counterfactual scenario simulates, as policy measure, a country-specific minimum level for gas in storage at the end of the calendar year. For each country, specific safe minimum levels of gas in storage for the end of the calendar year must be equal to or higher than 15 percentage points below the average storage filling level observed in the country during the period 2016-2018. This would ensure to meet a 55% target at EU level.

— A second counterfactual scenario introduces, on top of the previous minimum level at the end of the year, additional minimum levels for the gas in storage on 1 April and 1 October, i.e., the beginning and ending of the injection season.

Results

Results for the last three months of the year show that, for each test case, lower gas prices are found in the second counterfactual scenario (with storage obligations). The total cost of the gas supplies to EU consumers are shown to be substantially lower than the corresponding reference values. In fact, a major benefit can be observed in the pessimistic test case (high demand/reduced availability of extra EU supplies) due to the high prices derived from the baseline scenario. These benefits can be quantified as a reduction of cost for consumers up to 20% at EU level and it ranges between 10-30% across Member States. Needless to say, the economic benefits during the last three months of the year are due to two reasons: the obligation adopted to store gas at least to a given pre-defined level in October and the choice of the minimum storage level at the end of the year.

Acknowledgements

Authors

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1   Introduction

The EU Agency for the Cooperation of Energy Regulators (ACER) published in October 2021 a preliminary assessment ([3]) of the unprecedented high energy prices that European gas and electricity markets have reached and were continuously observed during the last quarter of 2021. Figure 1 represents the gas front month contracts from January to September 2021 in various gas hubs in Europe and it can be observed how gas prices have skyrocketed from August 2021 onwards. As rightly pointed out by ACER, this figure also illustrates the high level of gas market integration in Europe due to the price convergence. On 13 October 2021, the European Commission published a communication (European Commission, 2021) about tackling rising energy prices in which a toolbox has been presented for action and support.

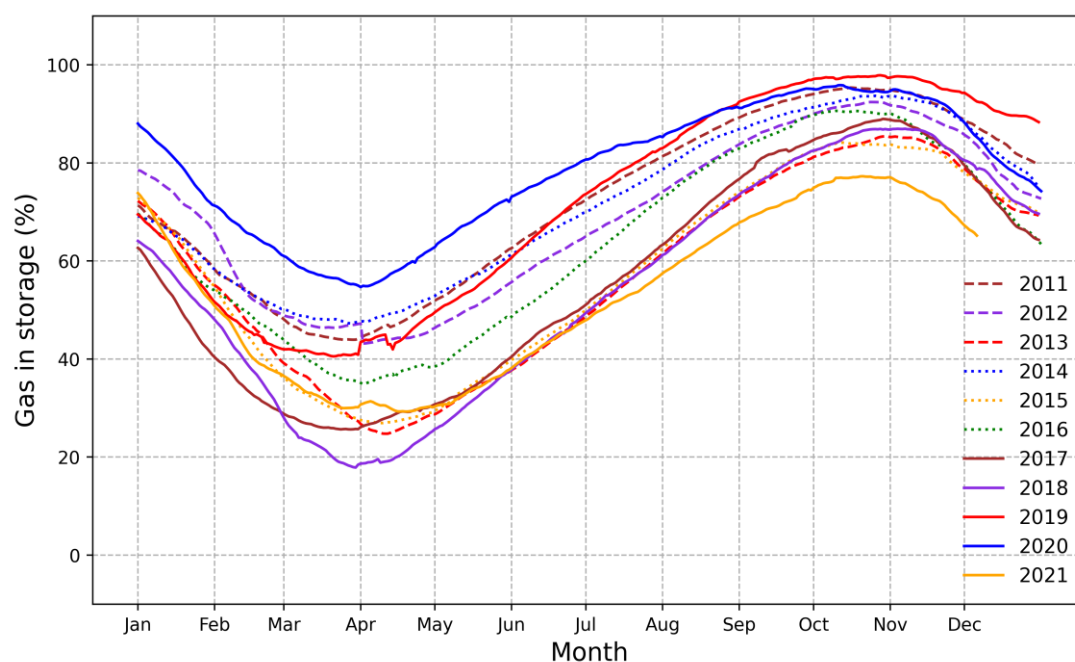Figure 1. Gas front month contracts from January to September 2021.
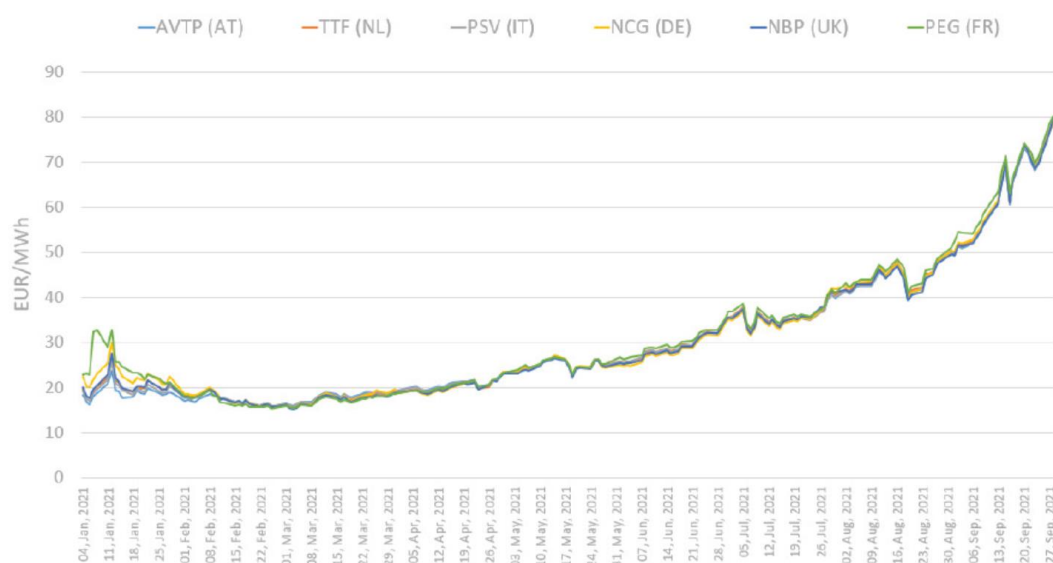
Source: ACER based on Reuters.

In addition, the rising of wholesale gas prices reflects the tight gas market situation in the European Union (EU). The current gas underground storage (UGS) filling level in the EU is the lowest out of the last 11 years at 65% (circa 721 TWh) of their total storage capacity on 6 December 2021, as can be seen in Figure 2. Figure 3 shows the corresponding disaggregated data per country with UGS on 6 December 2021. UGS filling level in Austria (AT) was around 43%, in the Netherlands (NL) around 51%, and Belgium (BE), Bulgaria (BG), Slovakia (SK), Sweden (SE), Germany (DE), Hungary (HU), Croatia (HR), Latvia (LV), and Romania (RO) kept their UGS filling level in the range (60%, 70%]. Only Poland (PL) presented a filling level over 80% (i.e. around 94%).

([3]) The ACER analysis is available at: https://www.acer.europa.eu/events-and-engagement/news/europes-high-energy-prices-acer-looks-drivers-outlook-and-policy

Figure 2. Gas storage filling level (%) in the EU over the last 11 years.

Source: JRC based on AGSI+ Transparency Platform.

Figure 3. Underground gas storage capacity in TWh, current level in TWh, and storage filling level in % on 6 December 2021. Note that areas of circles are proportional to the storage capacity, colour code indicates the filling level (green shades for EU MS; orange shades for non-EU countries), and the numbers shown in each circle corresponds to the current storage level.
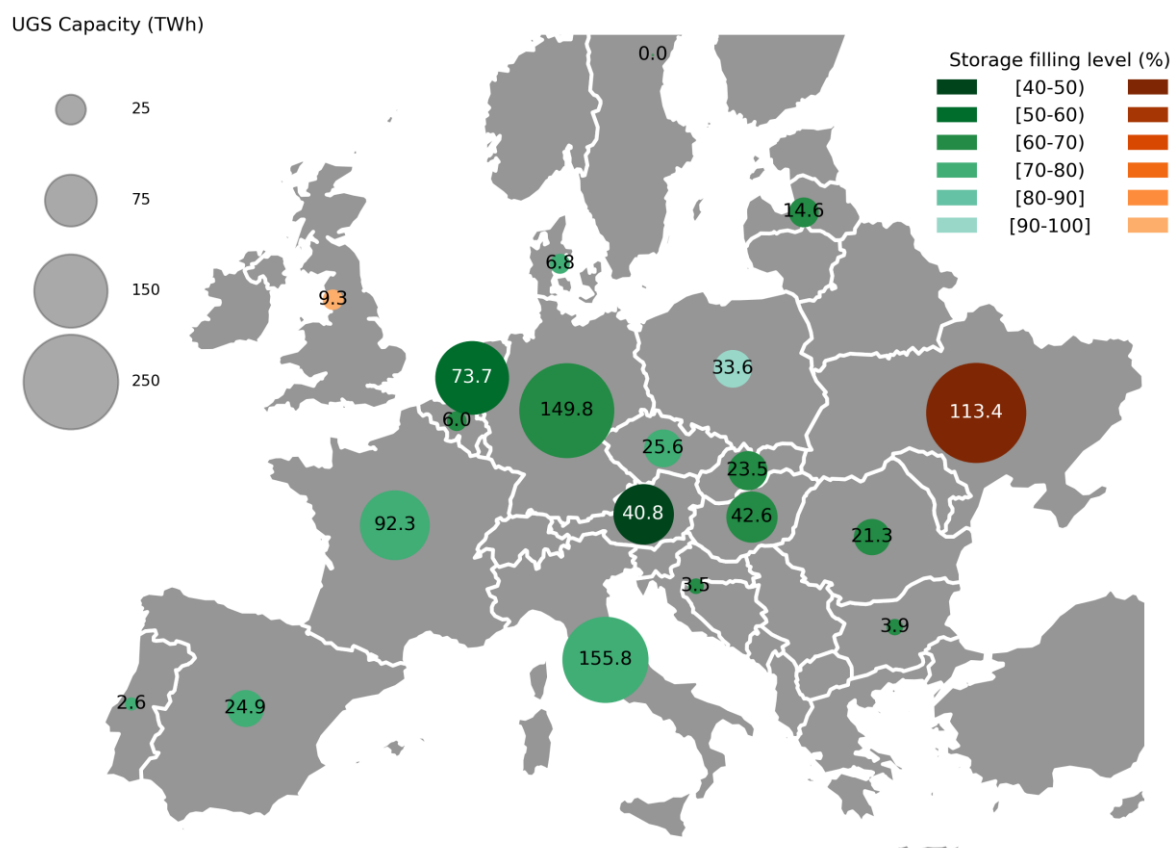
Source: JRC based on AGSI+ Transparency Platform.

Germany, Netherlands and Austria are key countries to ensure security of gas supply in the EU and their corresponding UGS capacity represent around 43% the total UGS capacity in the EU. However, UGS filling levels in NL and AT are the lowest across MSs and the storage level in DE, which is the country with the highest UGS capacity, i.e. 241 TWh (approx.. 23 bcm), is delayed with respect to previous years, mainly because of the low quantities of gas stored in the UGSs owned and/or operated by Gazprom (⁴). Figure 4 represents the gas storage filling level in the EU from 2016 until 2021 along with the filling level of the Gazprom-owned and/or operated UGSs and the filling level of those not owned/operated by Gazprom. The total EU UGS capacity amounts to 1106.6 TWh and the total capacity of Gazprom-owned and/or operated UGSs is 138.2 TWh. It can be seen that there was a full depletion of Gazprom-related UGSs in the first quarter of 2021. Levels have slightly increased in the last quarter before starting the withdrawal season. On 6 December 2021, the filling level of Gazprom-related UGSs is 22.4% of their corresponding capacity compared to the filling level in the EU of 71.3% of the UGSs which are not owned/operated by Gazprom.

Figure 4. Gas stored in EU underground gas storages in the period 2016-2021 compared to (i) the gas stored in Gazprom-operated storages (in yellow) and (ii) the gas stored in storages which are not owned or partially operated by Gazprom (in blue).
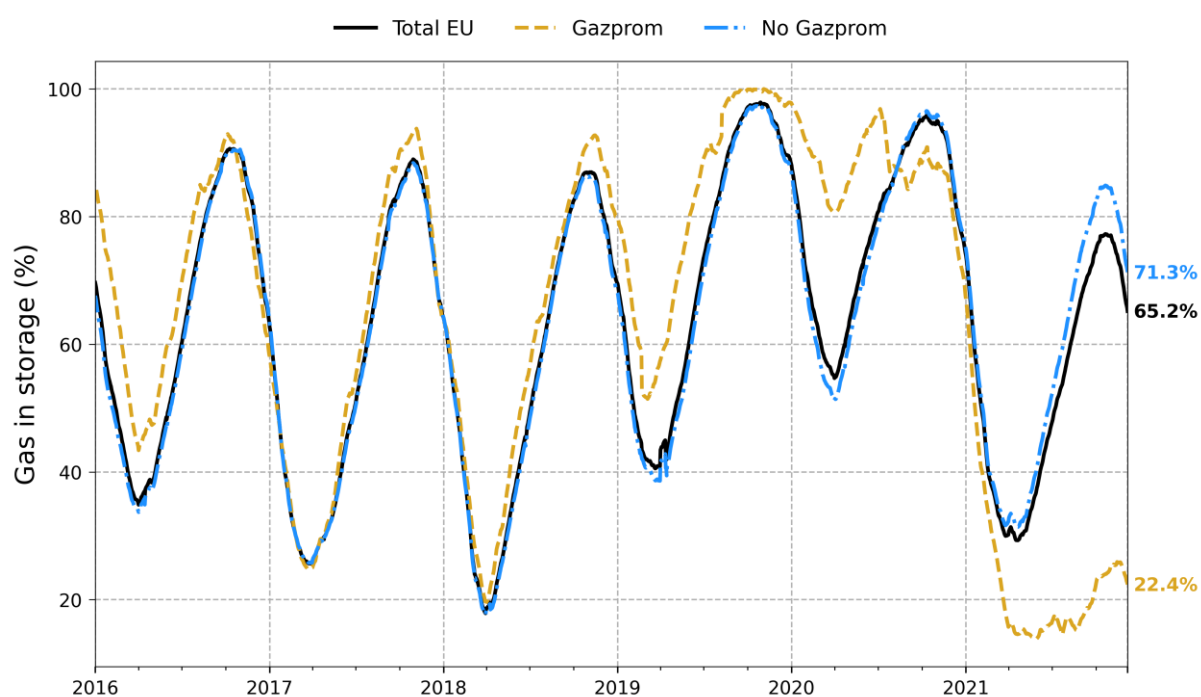
Source: JRC based on AGSI+ Transparency Platform.

Due to the sustained and persistent increase in gas prices observed in the last months of 2021, the Directorate-General for Energy (DG ENER) has requested the Joint Research Centre (JRC) to simulate the current short-term gas market using the gas module of the METIS software. The goal of this quantitative model-based analysis is to derive economic insights at EU level and explore some policy options. This report is part of a wider analysis of this subject which also includes the impact of gas prices on the electricity system and feedback effects between these two sectors (Kanellopoulos et al., 2022).

This work has been triggered by two evaluation questions:

— How does the filling level trajectory of seasonal EU underground gas storages drive gas prices in autumn and winter?

(⁴) UGSs fully or partially owned/operated by Gazprom in the Netherlands, Germany, and Austria are: UGS Bergemeer, UGS Jengum H (astora), UGS Rehden, VSP NORD (Rehden, Jengum), UGS Katharina, UGS Haidach (astora), and UGS Haidach (GSA).

— Would the establishment of minimum gas storage volumes at the beginning of winter have led to lower gas prices during September to November of 2021? How would the situation compare across Member States (MSs)?

The report is organised as follows. Section 2 describes the modelling approach and methodology. Section 3 provides a description of scenarios and test cases. Section 4 discusses the main technical and economic insights. Finally, Section 5 concludes the report and provides future research work.

2 Modelling approach

This exercise examines to what extent an obligation in refilling UGS in MSs could have affected the gas price levels observed along the summer and autumn 2021. To answer to this specific question, we have adopted a counterfactual approach applied to simulated gas market scenarios.

Counterfactual scenarios simulating the implementation of policy measures are compared with the state of the EU gas system/market with no measure in place (reference scenario). The comparison between each policy scenario and the reference one brings a quantitative assessment of the measure's impact.

A METIS "current context 2021" ([5]) has been built representing the technical and economic constraints of the EU gas system and market. This METIS context is run for one calendar year in daily time steps. In the 2021 time span, the reference scenario approximates supply and demand conditions observable from 1 January to 30 September. From 1 October to the end of the time horizon, the model endogenously allocates gas supplies to the EU gas market for three market conditions, which are described in detail in the next section.

METIS is an optimisation tool that provides a least-cost solution over a time horizon. It can be run over a perfect foresight condition. In this case, the perfect foresight model reproduces decisions taken when running the whole year in a single shot, i.e. market participants are perfectly aware of future events (e.g. gas demand) throughout the simulation horizon. Alternatively, it can be run over a rolling window with a look-ahead period. In this case, the optimisation model seeks the cost-efficient allocation based over a more limited timespan, iteratively repeating the optimisation exercise.

We apply the following methodological approach:

— First, we run a perfect foresight model with daily time steps for a yearly time horizon. From this simulation, cost-efficient UGS trajectories can be derived.

— Second, we run an imperfect foresight model, i.e. an optimisation problem with daily time steps for every week with a weekly look-ahead period. In this imperfect foresight model, we assume the previous UGS trajectories as minimum storage levels in order to guide the new trajectories towards the cost-efficient gas market simulated previously. The results from this model represent in a more realistic way the financial aspects of the gas market.

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[5]   A "context" in the METIS model describes an energy scenario modelled in METIS. A context includes all input data (list of modelled countries, asset parameters, time series …) for a given year but also the simulation results once the simulation is done. Running sensitivity runs on a given scenario would result in different METIS contexts, reflecting the same scenario, but with varying parameter values and results.

3 Description of scenarios and test cases

The reference or baseline scenario simulates the current 2021 gas market from 1 January until 1 October. During this period, the UGS trajectories are limited by lower and upper bounds to follow historical values.

In addition, two counterfactual scenarios are described as follows:

— A first counterfactual scenario simulates, as policy measure, a MS-specific minimum level for gas in storage at the end of the year. For each MS, specific safe minimum levels of gas in storage for the end of year must be equal to or higher than 15 percentage points below the average storage filling level observed in the country during the reference period 2016-2018. This would ensure to meet a 55% target at EU level. This counterfactual scenario is referred to as NO-MIN.

— A second counterfactual scenario, hereinafter referred to as OCT-MIN, introduces, on top of the previous minimum level at the end of the year, additional minimum levels for the gas in storage on 1 April and 1 October, i.e., the beginning and ending of the injection season.

For all scenarios, we run three different test cases, namely "optimistic", "base", and "pessimistic", depending on the gas demand level as well as LNG and Russian supplies to extra EU countries after 1 October and until the end of the simulation horizon.

In the following sections, we explain in more detail key parameters for all scenarios and test cases.

3.1 Gas demand

The gas demand follows 2021 actual figures until the end of September. The current figures have been downloaded from the corresponding Gas Transmission System Operators following the ENaGaD database (Zaccarelli et al., 2021). During the last three months of the year, the gas demand is different for each test case. The base case is assumed to follow 2016 gas demand for the same time period. The daily demand values for the optimistic (pessimistic) case are decreased (increased) by 10%. Figure 5 shows the daily gas demand in the EU for the simulation horizon for the three test cases.

Figure 5. EU gas demand in 2021. Historical values are used until the end of September. Three test cases are defined in the last three months of the year.
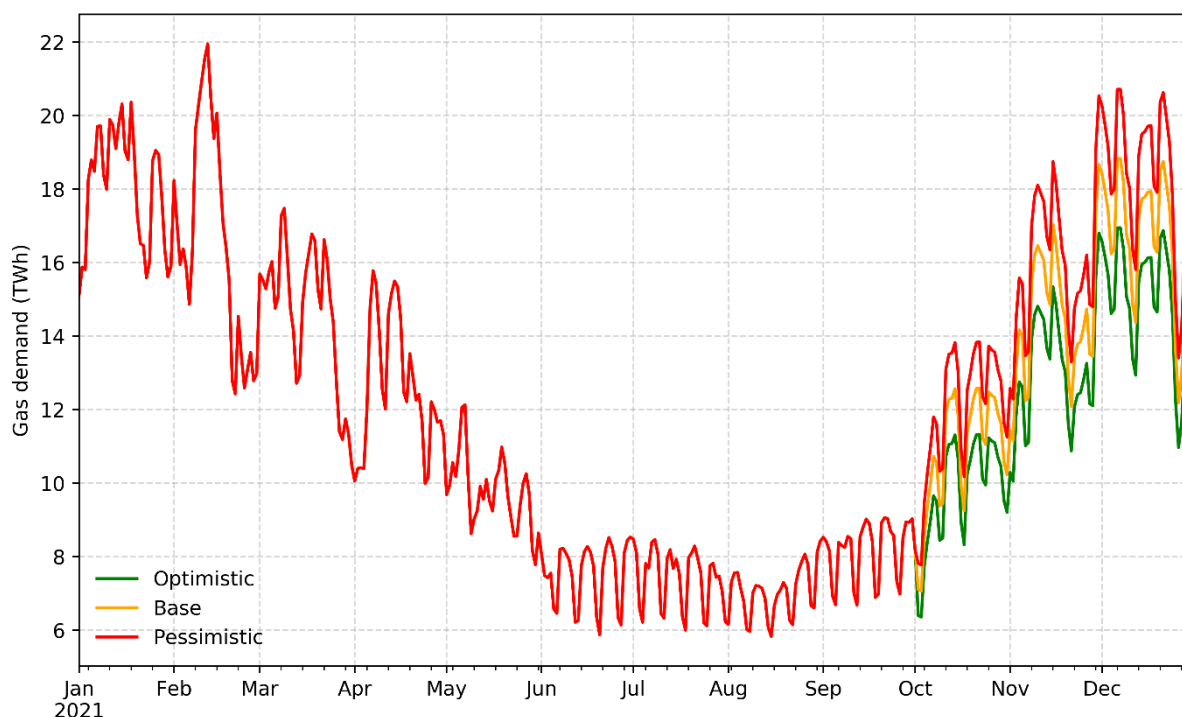
Source: JRC based on ENaGaD database.

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3.2 Russian gas supply capacity

Regarding the supplies from Russia (RU), a short-term production capacity is derived based on information over annual/monthly production. We assume that Russian expected production capacity is 690 bcm/year for 2021 ([6]) and this is converted to a production capacity ([7]) of 905.8 GW. Physical flows from RU to EU from January to September ([8]), if extrapolated to cover the year, bring a total of 163.2 bcm/year, i.e. 214.3 GW. Subtracting from the total production the expected supply capacity to EU, we derive a supply capacity to non-EU consumers (including Russian domestic demand and Russian exports to non-EU countries) of 526.8 bcm/year (692 GW). In the model, we assume a constant demand of Russian gas by non-EU consumers of this magnitude in the reference scenario. The non-EU demand is then modulated in order to simulate different levels of availability of natural gas to the EU system. It is increased by 10% from October onwards for the pessimistic test case and decreased by 10% for the optimistic one. These transitions are not stepwise but linearly increasing from 1 April until the end of September.

3.3 Liquefied natural gas supply capacity

The International Group of Liquefied Natural Gas Importers (GIIGNL) Annual market report (GIIGNL, 2021) provides a global view of the infrastructures that participate to the liquefied natural gas (LNG) supply chain. This source contains data on liquefaction and regasification terminals and data on trade flows under long-term and short-term contractual relationships, with detail on countries of origin and recipients.

For 2020, the global LNG production is reported at 357.1 MTPA, of which EU consumed 81.6 MTPA. In the METIS context 2021 the trade partners of EU are modelled in greater detail, with a supply cost function specifying costs on the upstream of the supply chain ([9]). In addition to that, we define a demand of LNG from extra European countries competing with EU demands, and an additional liquefaction capacity dedicated to the rest of the world. The possibility for EU countries to expand the usage of liquefaction capacities on the global market is limited by a maximum threshold of 100 GW, assumed to be attained by the major suppliers (50% by North America and 50% by Qatar). For the LNG producers currently having trade relationships with EU, we assume a fraction of the nominal capacity of liquefaction plants equal to the corresponding share of LNG production exported to EU. In the base case, the aggregate demand of LNG by non-EU consumers amounts at 481.7 GW, while the maximum liquefaction capacity that the model can allocate to EU consumption is 231.7 GW. The extra EU demand is used to represent scarcity conditions for EU consumers, competing on a global market. Specifically and similarly done with the demand of Russian gas for non-EU consumers, the demand of LNG by non-EU consumers is increased by 10% from October onwards for the pessimistic test case and decreased by 10% for the optimistic one. These transitions are linearly increasing from 1 April until the end of September. Table 1 shows the liquefaction capacities associated with each LNG market zone as well as the corresponding production shares to EU and non-EU countries.

Table 1. Liquefaction capacities in the EU and global market of LNG.

Zone	Liquefaction capacity (MW)	Production share to EU countries (%)	Production share to non-EU countries (%)
Algeria	43 179	93	7
Egypt	20 821	25	75
West Africa	44 203	50	50
Norway	7 168	97	3
Russia	47 719	69	31
South America	26 112	47	53
North America	130 135	13	87
Middle East	120 150	1	99
World	774 495		

Source: JRC on GIIGNL data.

([6]) October YoY from S&P.
([7]) We assume that 1 bcm/y of natural gas equals to 1 312.8 MW by using a gross calorific value (GCV) of 11.5 KWh/Nm^3 (https://www.fluxys.com/en/products-services/empowering-you-unit-converter).
([8]) Daily data are available from the GAZPROM website at https://www.gazprom.com/investors/disclosure/actual-supplies/.
([9]) https://www.rystadenergy.com/energy-themes/supply-chain/cost-and-prices/ (Rystad data, 2020).

3.4 Liquefied natural gas regasification terminals

The modelling of LNG regasification terminals in METIS is based on data from the Aggregated LNG Storage Inventory (ALSI) [10]. EU countries with an LNG regasification capacity are BE, Spain (ES), France (FR), Greece (GR), HR, Italy (IT), Lithuania (LT), NL, PL, and Portugal (PT). LNG regasification capacity in United Kingdom (UK) is also explicitly modelled. The main parameters for the modelling of the EU LNG regasification asset are the following:

— Initial and maximum stored volumes.

— Maximum send-out rate from the LNG facility to the natural gas grid.

— Maximum injection rate into the LNG storage at the offloading of cargoes. Injection rates and frequencies of arrival of cargoes are estimated from ALSI Transparency platform for each country with LNG regasification terminals for the period spanning from 1 January until 1 October. From October onwards, we assume a full availability of cargoes every three days. The LNG availability in PT, ES, Ireland (IE) and GR are, however, assumed equal to 1 at all times during the year in order to avoid unserved gas demand.

3.5 Cross-border interconnection capacities

The cross-border interconnection capacity between two countries is modelled as an aggregated transmission capacity representing all the pipeline interconnections among those countries. Values of the maximum technical capacities come from the ENTSOG Capacity Map 2021 [11].

3.6 European indigenous production

Indigenous production of natural gas is specified in the model for AT, BE, BG, Czechia (CZ), DE, Denmark (DK), ES, FR, GR, HR, HU, IE, IT, NL, PL, RO, (Slovenia) SI, and SK. Also UK is explicitly modelled as a gas producer. Eurostat monthly data are used to define a maximum production capacity. The missing months are obtained by extrapolation to the end of the time horizon of the last available observation, given the substantial stability of the production levels in EU MSs.

3.7 Gas in storage settings

The level of gas in storages at the end of the calendar year is maintained above or equal to a threshold value for all scenarios. In principle, it is a safe minimum preventing excessive depletion of gas from UGSs, i.e. avoiding issues of affordability and availability of gas in subsequent seasons. To determine this parameter, we can refer to historical data from the AGSI+ transparency platform. In Figure 6 the yellow line shows the observed trend for gas in storage in 2021, while the blue dashed line and the blue shaded area are projections derived from the minimum, average, and maximum daily withdrawals observed in the corresponding period of the season from the last six winters (from December 2015 until March 2021). In this figure, we can observe that the average storage filling level at the end of the year 2021 is around 55%, which is 15 percentage points below the mean storage filling level at that specific time from the reference period 2016-2018. Trajectories falling below this level on 31 December 2021 may jeopardise security of supply during the rest of the gas year. The curve is an illustrative projection of what may happen if withdrawals followed favourable or unfavourable patterns in the coming months [12]. The main output of this figure is the derivation of uncertainty ranges for the storage filling level per time period. Note that the 55% level is not applied uniformly on each MS, but each MS with storage has a corresponding threshold that varies across countries and it is derived based on the average level from the reference period 2016-2018.

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[10] Aggregated LNG Storage Inventory is a dataset promoted by LNG Storage Operators (LSOs) providing daily data on terminals. The source is available at https://alsi.gie.eu/#/.

[11] Available at https://www.entsog.eu/maps#transmission-capacity-map-2021

[12] In this illustrative projection, we have not taken into consideration explicit deliverability UGS curves, which may slow down the depletion of UGS as the filling level decreases.

Figure 6. Gas storage evolution in 2021 (yellow) and projections until the end of March 2022.
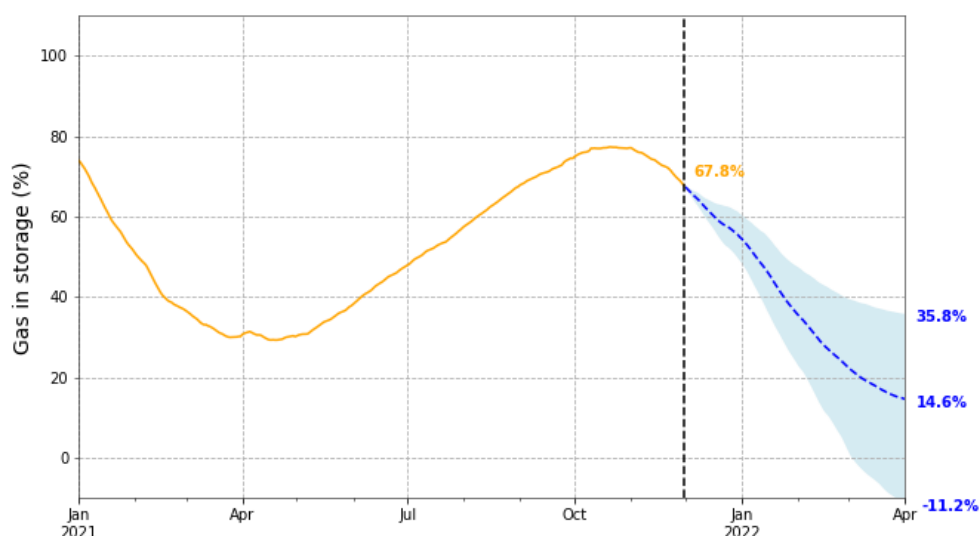
Finally, the second counterfactual scenario OCT-MIN imposes minimum storage levels per country with UGS on 1 April and 1 October. Figure 7 provides some descriptive statistics on UGS filling levels per country including UK and Ukraine (UA). In this figure, we represent the minimum and maximum filling levels out of the 11 years for which data are available. Imposing the historical maxima as minimum levels on 1 October might be too stringent. For this reason, we have chosen, for each EU MS, the average filling levels during the reference period 2016-2018 for the corresponding dates. In the figure, we also show the average values over the 11 years for which data are available, for the sake of comparison. It is clear that there is a huge variability across MSs. As a final remark, the UGS in UK and UA follows the same strategy as the one assumed in the baseline scenario, i.e. we set minimum storage levels until the end of October in UK based on the 2021 historical observations, and a guiding curve for UA UGS until the end of October as well.

Figure 7. Descriptive statistics on underground gas storage filling levels (%) per country. Green markers may be suitable values for imposing minimum levels in 1 October while red values may be suitable for 1 April.
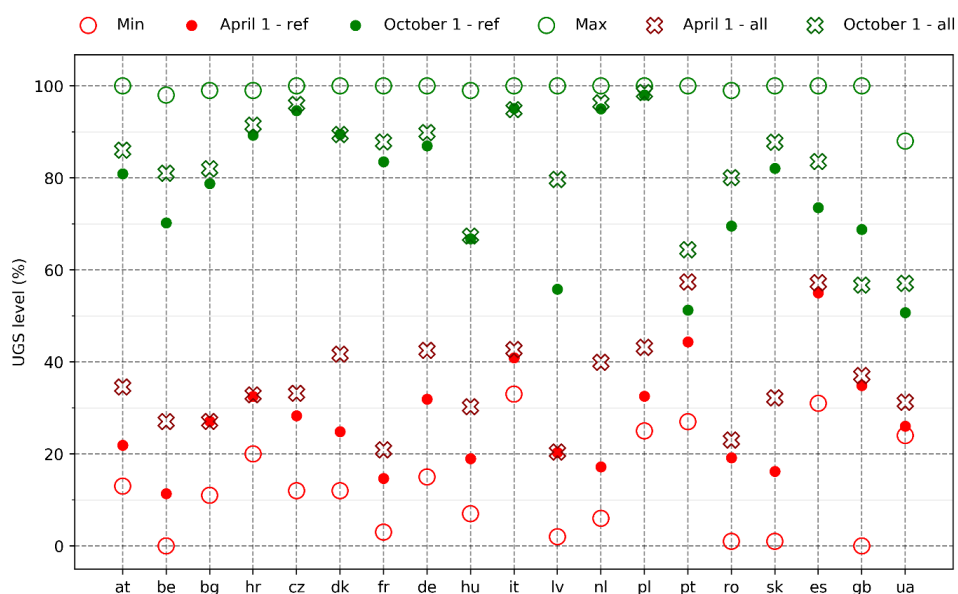
4 Discussion of results

Results are discussed from two perspectives. On one hand, the gas storage evolution aggregated at EU level is compared across scenarios and test cases in order to understand the general behaviour of each simulation. On the other hand, economic outputs such as marginal prices, social welfare, consumer and producer surplus, as well as consumer payments are subsequently analysed.

4.1 Gas storage evolution

Figure 8-Figure 10 show the EU gas storage evolution in 2021 until 6 December, the average storage level during the reference period 2016-2018, and the results from the three scenarios (Baseline, NO-MIN, OCT-MIN) for the test cases optimistic, base, and pessimistic, respectively.

The gas storage evolution from the baseline scenario (green dashed line) follows the historical one (yellow line) since guiding curves are used until the end of October. From October onwards, the green curve is fitting better in the base or even in the pessimistic test case.

The NO-MIN scenario does not impose any additional constraint on storages apart from the initial and final storage level condition. Therefore, this curve would represent the optimised trajectory without storage obligations based exclusively on the technical and economic limitations assumed in the baseline scenario. For this reason, we can observe that UGS is over utilised in the optimistic test case in which gas demand is relatively low at the end of the year and the supplies to extra EU countries are also low (Figure 8), thus leading to a lower level of gas in storage. On the other hand, UGS seems to be underutilised in the pessimistic test case given the tight market situation due to high gas demand and high supplies to extra EU countries (Figure 10), thus leading to a higher level of gas in storage. As expected, the storage evolution in the base case under NO-MIN scenario follows the historical filling level (Figure 9).

Regarding the second counterfactual gas scenario OCT-MIN, in which we impose storage obligations or storage minimum levels on 1 April and 1 October, the storage level evolution differs from case to case. In the optimistic and base test cases, we can observe a peak in 1 October and this is an indication that the storage obligation in October might be too stringent for the market conditions considered in those cases. From July-August until October, it can be seen a high injection in UGSs compared to the other two scenarios. In the pessimistic case wherein a tight market situation takes place, the storage filling level on 1 October goes over the pre-defined minimum. In fact, an unconstrained simulation (first counterfactual scenario) leads to the same results.

Finally, the depletion of UGSs in the EU causes the attainment of the minimum storage level imposed at the end of the simulation horizon, i.e. 55% at EU level, for all test cases and scenarios. This happens because the optimisation is myopic and does not take into account that, during the rest of the winter, the gas demand will continue probably high.

Figure 8. EU gas storage evolution in 2021, reference period 2016–2018, and three scenarios for the optimistic test case.
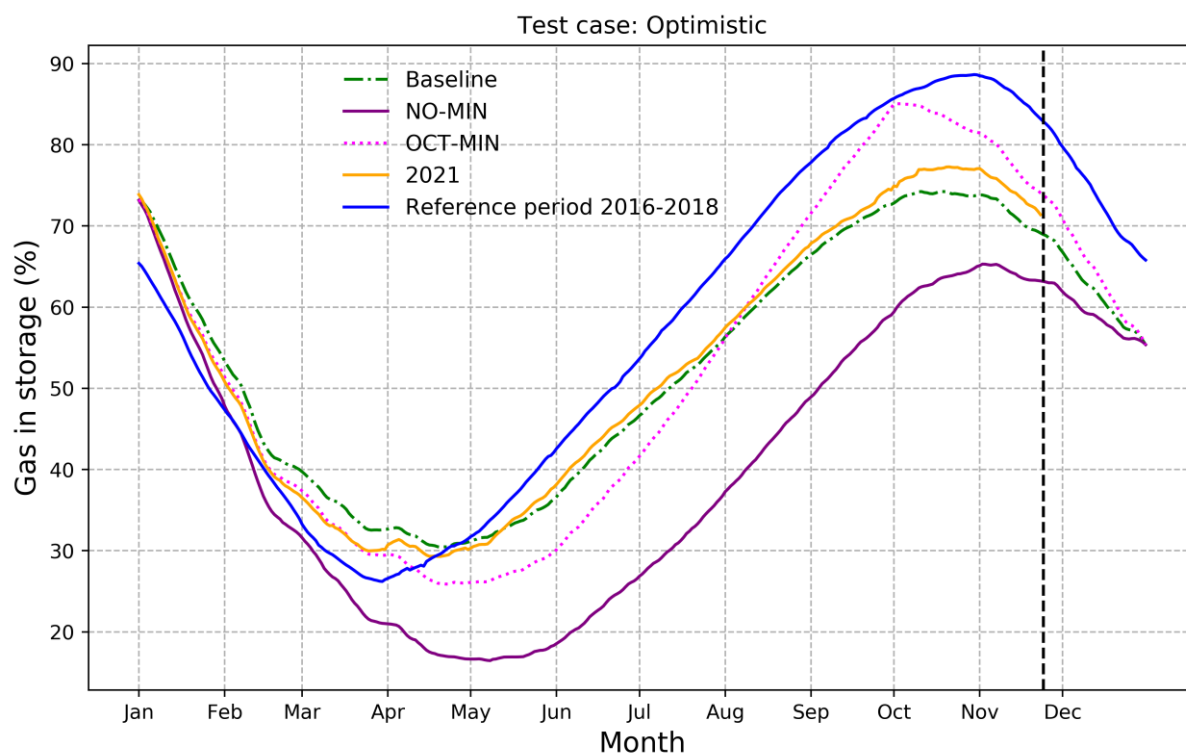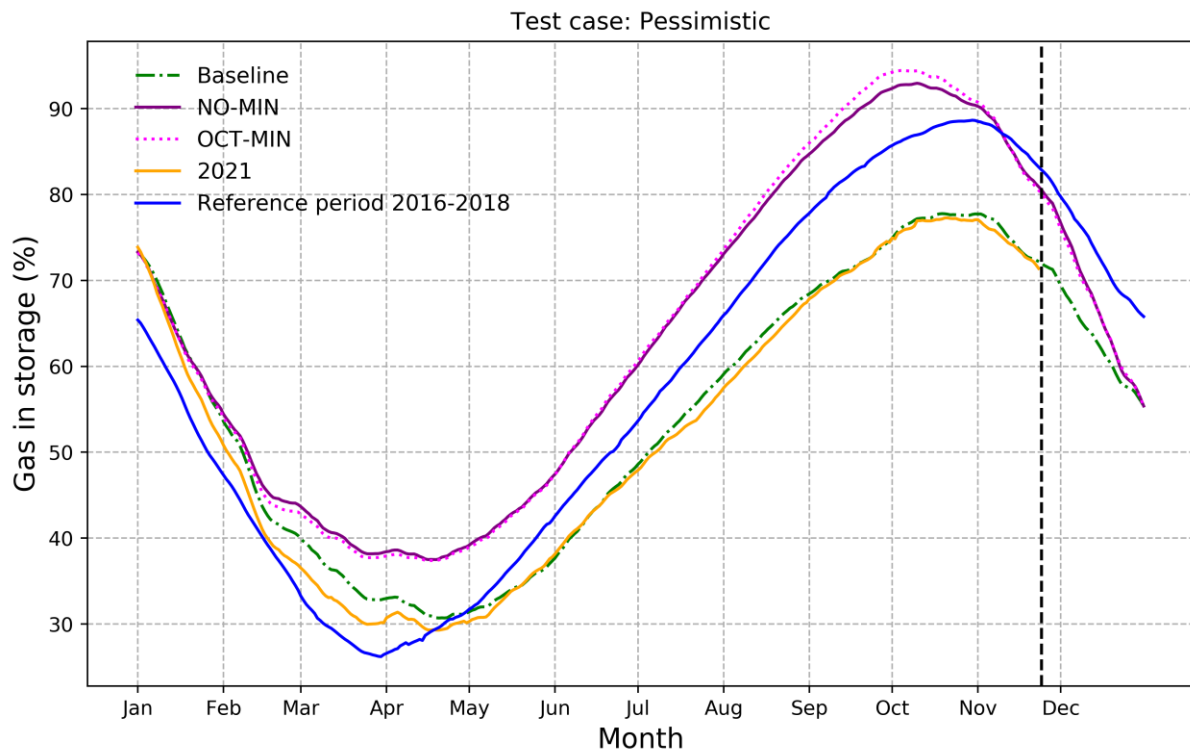

Source: JRC based on AGSI+ Transparency Platform.

Figure 9. EU gas storage evolution in 2021, reference period 2016–2018, and three scenarios for the base test case.
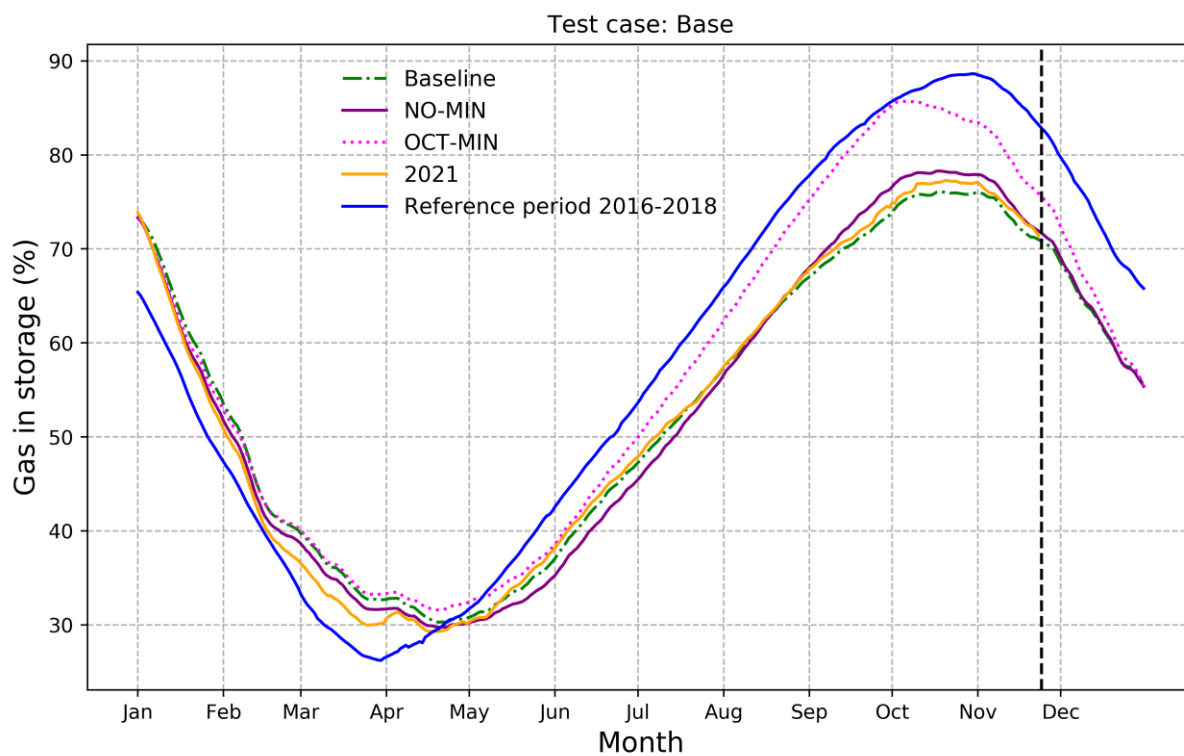
Source: JRC based on AGSI+ Transparency Platform.

Figure 10. EU gas storage evolution in 2021, reference period 2016-2018, and three scenarios for the pessimistic test case.

Source: JRC based on AGSI+ Transparency Platform.

4.2 Marginal prices

One of the main outputs of METIS is the nodal or zonal shadow prices that are assumed as proxy for values of spot market prices. Figure 11-Figure 13 show the daily prices averaged over all EU countries (except for Malta and Cyprus) for all scenarios and the optimistic, base, and pessimistic cases, respectively.

The prices reflect to some extent the utilisation of UGSs to satisfy the gas demand. In the optimistic case study (Figure 11), the stringent policy imposed in October in the scenario OCT-MIN leads to higher injections from July until October than in the other two scenarios. Thus, higher prices can be observed during this period in this scenario. However, thanks to a higher filling level at the beginning of the withdrawal season, marginal prices are lower during the last three months of the year. This pattern can be also noticed, to a lesser degree, in the base test case (Figure 12).

In the pessimistic test case (Figure 13), the tight market situation leads to price spikes around 90 €/MWh in the last three months of the year, thus the benefits from injecting gas during summer are evident because average marginal prices are kept below 40 €/MWh at all times throughout the simulation horizon. Figure 14 shows the monthly price changes of the second counterfactual scenario OCT-MIN with respect to the values from the baseline scenario for the three test cases. In this figure, we can observe that the prices decrease up to 40-50% in November and December by fulfilling minimum storage levels in 1 October.

Figure 11. Average marginal prices across EU Member States for the three scenarios in the optimistic test case.
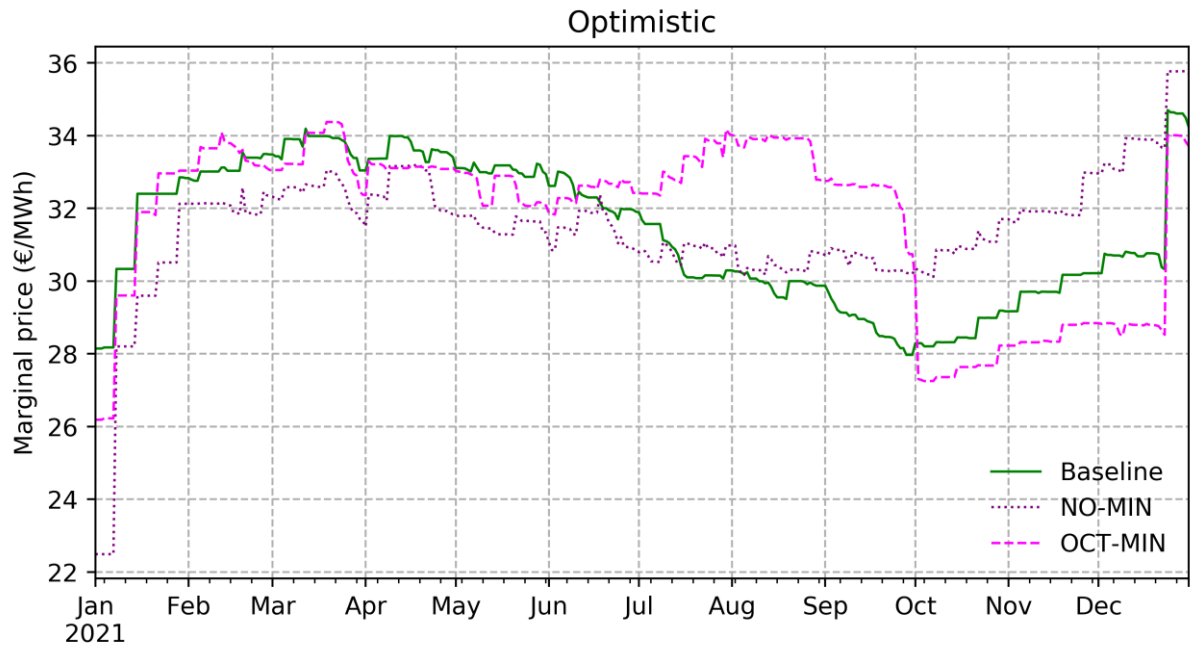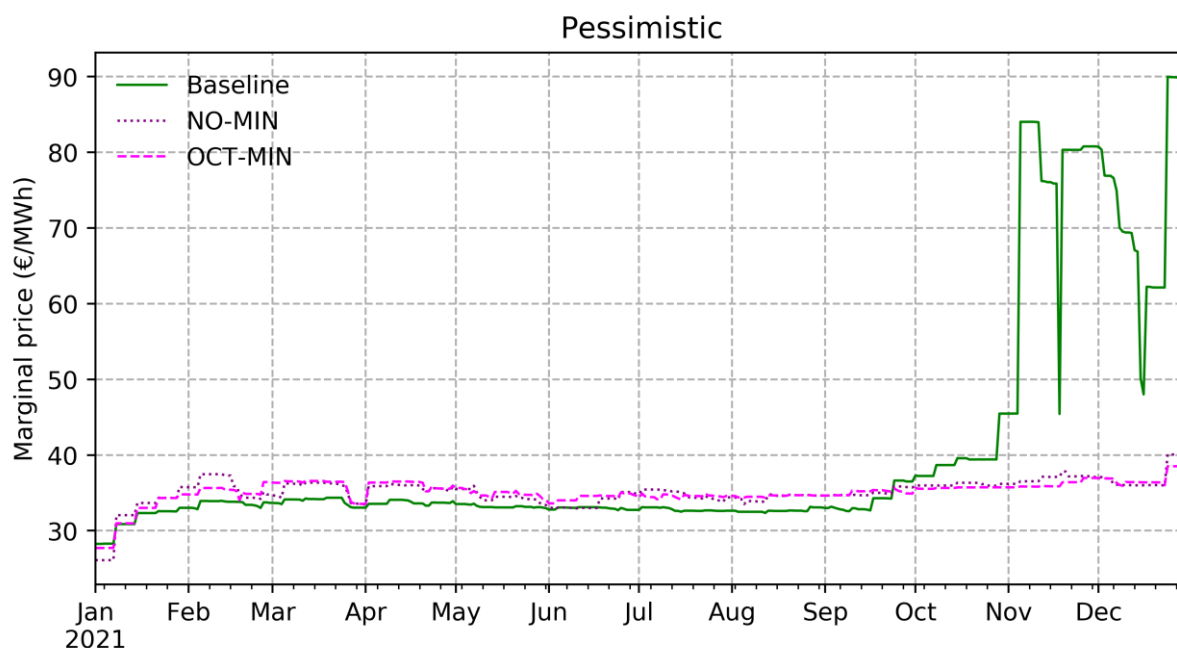

Source: JRC.

Figure 12. Average marginal prices across EU Member States for the three scenarios in the base test case.
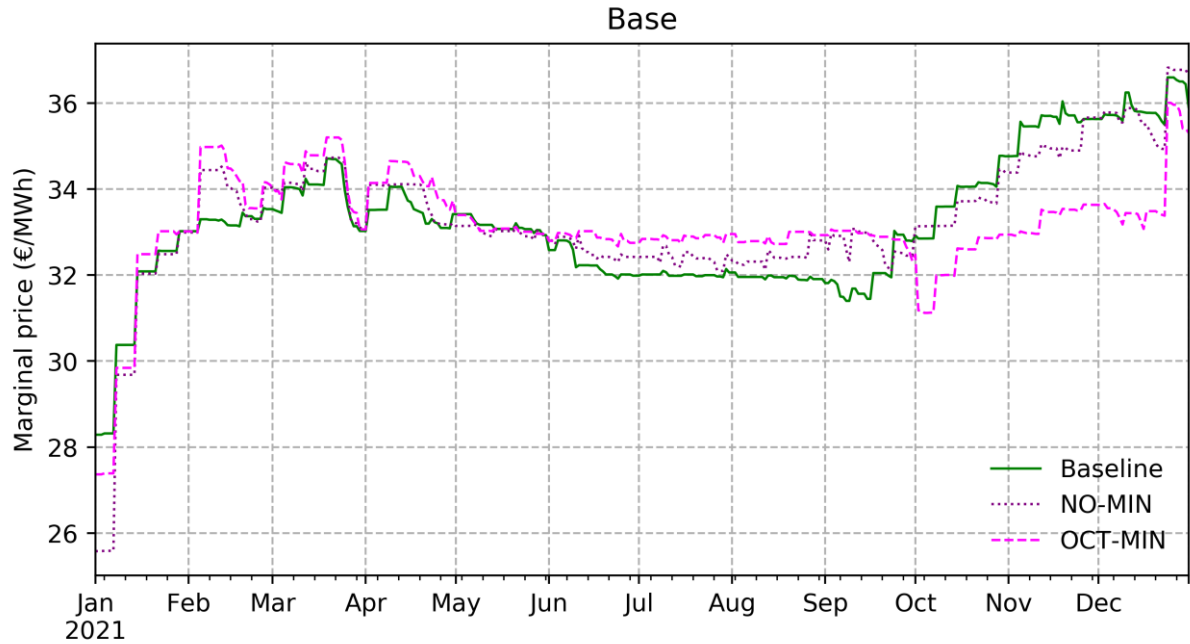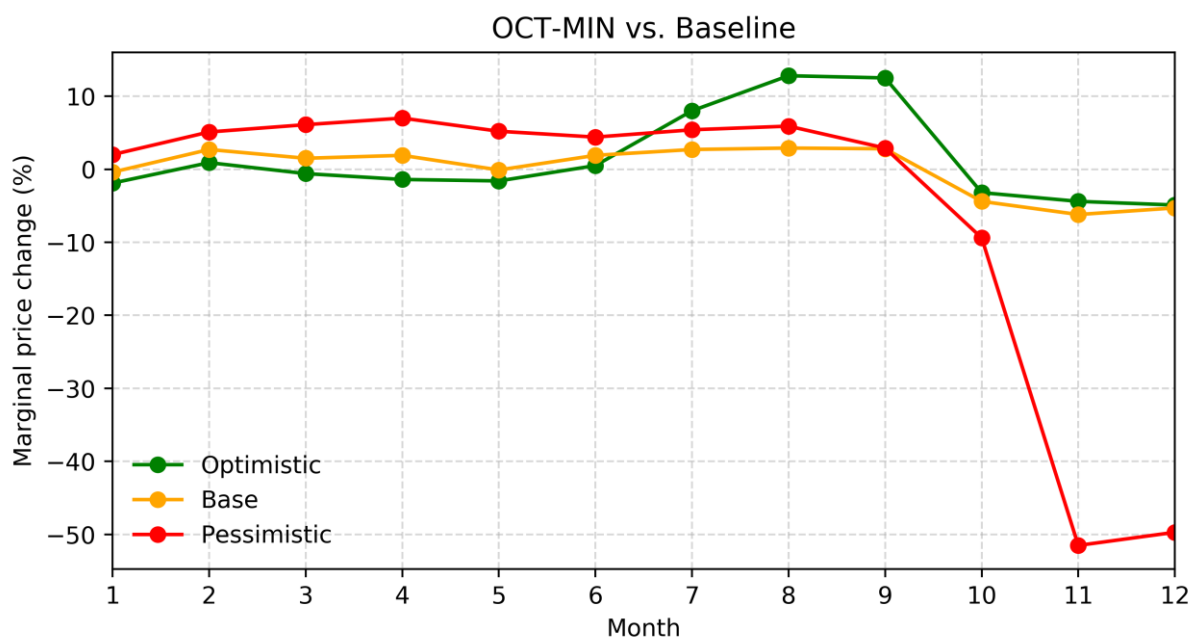

Source: JRC.

Figure 13. Average marginal prices across EU Member States for the three scenarios in the pessimistic test case.

Source: JRC.

Figure 14. Monthly changes in average EU marginal prices of the second counterfactual gas scenario (OCT-MIN) with respect to the reference scenario.

Source: JRC.

4.3 Economic-related outputs

Table 2 presents variations of the following financial indicators for the counterfactual gas scenarios with respect to the reference scenario: producer surplus, consumer surplus, social welfare, and consumer payment. The first three parameters are direct outputs from the METIS software, while consumer payment is computed based on the marginal prices and gas consumption per country. All parameters are accumulated values over the year for EU countries. For each counterfactual, we show the impact in relative terms and in billion EUR.

In the reference scenario, the tight market situation modelled in the pessimistic case study leads to a reduction in the social welfare at EU level by 36% and 24% compared to the optimistic and base cases, respectively. This is translated into higher consumer payments, i.e. 48% and 36% higher than in the optimistic and base cases.

The unconstrained optimisation scenario NO-MIN, for which no additional storage obligations are used in October and April, leads to different results depending on the test case. In the optimistic test case, there is a reduction in the producer surplus up to 3.5% with respect to the one in the reference scenario driven by the low gas demand. The base test case gives rise to the same results as the ones observed in the reference scenario and this is corroborated by the EU storage evolution (Figure 9). Finally, as expected, the results from the NO-MIN scenario are aligned to the ones given by OCT-MIN in the pessimistic case due to the high gas demand and high supplies to extra EU countries.

Finally, imposing minimum storage obligations in 1 October and 1 April (OCT-MIN scenario) leads to an increase of the social welfare by 12% and a decrease of approximately 20% in consumer payments when a tight market situation is expected (pessimistic test case). However, in the optimistic case, there is a slightly decrease of 1.6% in social welfare and a small increase of 3.3% in the consumer payment. The results for the base case are more aligned to the ones from the pessimistic case, although the relative changes are negligible compared to the pessimistic market conditions.

Table 2. Variations of financial indicators under the analysed measures for the three scenarios and three test cases.

Test case	Output	Impact NO-MIN measure (%)	Impact OCT-MIN measure (%)	Impact NO-MIN measure (billion EUR)	Impact OCT-MIN measure (billion EUR)
Optimistic	Producer surplus	-3.5	-9.2	-0.8	-2.1
	Consumer surplus	0.1	-0.2	0.1	-0.3
	Social welfare	-0.5	-1.6	-0.5	-1.7
	Consumer payment	-0.1	0.3	-0.1	0.4
Base	Producer surplus	-0.4	-3.3	-0.1	-0.8
	Consumer surplus	-0.3	0.6	-0.5	1.0
	Social welfare	-0.2	0.4	-0.2	0.5
	Consumer payment	0.2	-0.7	0.3	-1.0
Pessimistic	Producer surplus	-43	-44.3	-19.8	-20.4
	Consumer surplus	18.4	18.7	38.9	39.5
	Social welfare	12	12	17.7	17.7
	Consumer payment	-19.5	-19.9	-38.8	-39.6

Source: JRC.

Figure 15 compares the relative changes in annual consumer payments of the counterfactual gas scenario OCT-MIN regarding the reference scenario across MSs for the pessimistic test case. There is a general trend in consumer payment reductions between 10-30%. We can observe rather small reductions in Portugal and Spain, while there are small increases around 2% in Greece and Bulgaria. This can be explained by the higher availability of LNG cargoes in Spain, Portugal and Bulgaria in order to avoid gas shortages, which helps alleviate the tight market situation even in the reference scenario.

Figure 15. Consumer payment changes per country in OCT-MIN scenario compared to baseline scenario for the pessimistic case study.
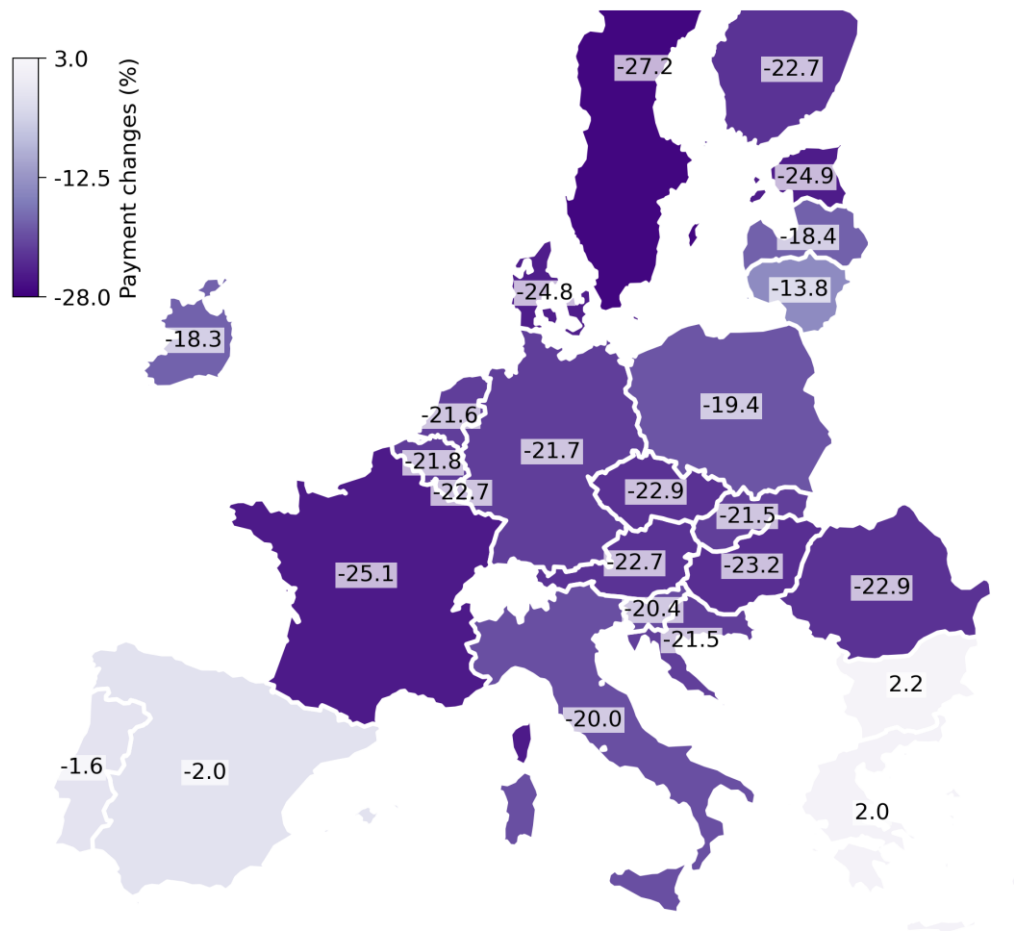
5   Conclusions

DG ENER has requested the JRC to simulate the current gas market situation by using a quantitative gas market model given the current tight gas market situation and unprecedented high energy prices observed in Europe during the last quarter of the year. Lately, international organisations such as the European Commission and ACER have paid closer attention to the recent developments on energy markets. Specifically for the case of gas markets, JRC monitors continuously the physical supplies from third countries outside the EU, the evolution of gas stored in UGS, and the LNG figures on a daily and weekly basis.

This report explores simulated policy options to derive potential insights on the financial impacts at EU level and provides preliminary results about the implications of imposing minimum gas storage volumes at the beginning and ending of the injection season. The analysis has considered various levels of gas scarcity due to both supply and demand factors, describing to which extent the use of UGS could have lowered natural gas prices and their impacts on EU consumers. Hypothetical targets for the gas in storage, designed for the calendar year 2021, were derived from the state of the gas system and market during previous years. These 'obligation' measures prevent a substantial deviation from past observable (and desirable) ordinary conditions (e.g. avoiding extremes as depleted storages). This can be deemed a measure to ensure affordability with respect to the 2021 gas market situation of energy price spikes during September, October and November in most Member States.

Specifically, this study shows preliminary economic and technical results on the impact of imposing country-specific minimum storage levels with respect to a baseline scenario simulating the current market conditions until October 2021. Three test cases have been analysed depending on the gas demand level and scarcity of supplies to extra EU countries. Results for the last three months of the year shows that, for each test case, lower gas prices are found in the counterfactual scenario with storage obligations. The total cost of the gas supplies to EU customers are shown to be substantially lower than the corresponding reference values. In fact, a major benefit can be observed in the pessimistic test case (high demands/reduced availability of extra EU supplies) due to the high prices derived from the baseline scenario. These benefits can be quantified as a consumer payment reduction up to 20% at EU level and it ranges between 10-30% across Member States. Needless to say, the economic benefits during the last three months of the year are due to two reasons: the obligation adopted to store gas at least to a given pre-defined level in October and the pre-defined boundary condition on minimum storage levels at the end of the year.

A follow-up work is foreseen to further develop this research:

— Given the increasing importance of analysing the ongoing heating season, we plan to switch the simulation horizon to cover the gas year. For this time horizon, we can still simulate the behaviour of the gas system in 2021 until October. From October onwards, a number of test cases could be defined based on 2016 gas demand and assumptions on availability of extra EU supplies, as similarly done in this study. This time horizon would allow for a more rigorous analysis of the consequences during the gas year of imposing minimum storage levels in October.

— Sensitivity analyses can be performed on two aspects: (i) gas storage obligations on 1 October, and (ii) gas demand. Results will be focused on economic and technical indicators: gas marginal prices; financial indicators such as social welfare or consumer payment; and gas storage levels throughout the simulated horizon.

— The minimum gas storage obligation on 1 October may affect the gas consumption for electricity production throughout the year, especially in summer in which the underground gas storages tend to increase their injections to fulfil the minimum level constraint. Then, it would be interesting to run an integrated electricity and gas context.

References

ACER, *High energy prices*, European Union Agency for the Cooperation of Energy Regulators, October 2021. https://documents.acer.europa.eu/en/The_agency/Organisation/Documents/Energy%20Prices_Final.pdf.

Zaccarelli, N., Giaccaria, S., Feofilovs, M., Bolado Lavin, R., *The European Natural Gas Demand database (ENaGaD)*, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-40208-4, doi:10.2760/497677, JRC125730, https://data.europa.eu/doi/10.2760/497677.

European Commission, *Communication from the commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. Tackling rising energy prices: a toolbox for action and support*, Brussels, 13 October 2021, COM(2021) 660 final. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0660&from=EN.

GIIGNL, *GIIGNL Annual Report*, the LNG industry, 2021. https://giignl.org/wp-content/uploads/2021/11/GIIGNL_Annual_Report_November2021.pdf

Kanellopoulos K., De Felice M., Busch S., Koolen D., *Simulating the electricity price hike in 2021*, EUR30965 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-46577-5, doi:10.2760/950989, JRC127862.

List of abbreviations and definitions

ACER	Agency for the Cooperation of Energy Regulators.
AGSI	Aggregated gas storage inventory.
ALSI	Aggregated LNG storage inventory.
AT	Austria.
BE	Belgium.
BG	Bulgaria.
CZ	Czech Republic.
DE	Germany.
DK	Denmark.
DG-ENER	Directorate-General for Energy.
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.
GIIGNL	International Group of Liquefied Natural Gas Importers.
GR	Greece.
HR	Croatia.
HU	Hungary.
IE	Ireland.
IT	Italy.
JRC	Joint Research Centre.
LNG	Liquefied natural gas.
LSO	LNG Storage Operator.
LV	Latvia.
MS	Member State.
MTPA	Million Tonnes Per Annum.
NL	Netherlands.
PL	Poland.
PT	Portugal.
RO	Romania.
RU	Russia.
SE	Sweden.
SI	Slovenia.
SK	Slovakia.
UA	Ukraine.

UK   United Kingdom.

UGS   Underground Gas Storage.

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