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DE-RISKING GAS STORAGE IN UKRAINE: THE INDEPENDENT TECHNICAL REVIEW OF STRESS-TEST SCENARIOS FOR THE 2023/2024 WINTER SEASON

I. PROJECT BACKGROUND

In addition to the normal seasonal price dynamics in natural gas markets, the coming 2023/2024 winter season poses an acute risk of natural gas price volatility in the European Union (EU) spot markets. This volatility is partially driven by reductions in Russian supplies during the last years, and it might become more acute under a prolonged cold winter and if demand is high in other global gas markets. This situation would reduce gas affordability for EU customers and might cause negative economic consequences for the EU member states.

Considering that European storage facilities—driven by Regulation (EU) 2022/1032¹—have reached around 90 percent of their capacity as of August 23, 2023², the additional available gas storage facilities in Ukraine offer the EU an important option to ensure uninterrupted energy availability and mitigate price spikes in the spot market. Given the ongoing war, Ukraine’s authorities and state-owned gas operators have acknowledged the risks that European traders have perceived as obstacles to storing gas in Ukraine.

This public note seeks to bring additional assurance and clarity to European companies interested in using Ukrainian gas storage and transmission infrastructure during the 2023/2024 winter season by assessing whether stored gas intended for the EU is at risk due to full-scale Russia’s invasion of Ukraine against the gas infrastructure of Ukraine³.

2. EXECUTIVE SUMMARY

Underground gas storage (UGS) facilities are crucial infrastructure facilities that are commonly used to secure the gas supply during the winter peak demand. They are also valuable in addressing both seasonal and short-term market volatility. Therefore, maximizing the efficient utilization of all storage capacities across Europe for the upcoming winter is of utmost significance.

At the time of writing (August 23, 2023), EU gas storage facilities were at 90 percent of their capacity. This means using the additional available gas storage facilities in Ukraine will be important to guarantee continuous energy availability and mitigate spikes in spot market prices. While Ukraine boasts the largest storage capacities in Europe and the third largest globally, attracting European traders to use these extensive facilities requires more than just market conditions (which are already in place); it also requires an analysis of potential physical damage to the facilities due to the Russian Federation’s ongoing war against Ukraine. This note adds that purpose: to assess different risk scenarios that would have an impact on the

¹ 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 <https://eur-lex.europa.eu/eli/reg/2022/1032/oj>

² https://energy.ec.europa.eu/news/eu-reaches-90-gas-storage-target-ahead-winter-2023-08-18_en

³ Verified and confirmed by the independent international auditor Simone Research Group (SRG), selected in agreement with all involved stakeholders and engaged by USAID ESP.

functioning of Ukrainian UGS facilities and the relevant gas infrastructure and EU customers' ability to withdraw gas.

This project had the following main objectives:

- 1) Define stress-test scenarios with realistic combinations of possible asset outages caused by military attacks and severe market conditions happening simultaneously. The scenarios, defined by the working group, sought to test the hypothesis that gas could be evacuated in case of emergency during the 2023/2024 winter season.
- 2) Model the operation of Ukraine's gas transmission and storage systems under stress scenarios with potential physical damage to key storage and transmission assets.
- 3) Using an independent international auditor, perform an independent technical review of the modeling results⁴. The auditor's job was to verify that the modeling results are accurate and realistic.
- 4) Determine whether Ukraine's gas infrastructure can evacuate of the anticipated gas volume stored under the UGS "customs warehouse" regime during winter 2023/2024 under the stress scenarios.

Due to the risks associated with sharing sensitive technical information related to national infrastructure during Russian aggression against Ukraine, the technical results of this project cannot be shared publicly at this time. Therefore, in order to provide confidence to market participants that the conclusions are accurate, this study was conducted in close cooperation with the EnCS and the JRC⁵ of the European Commission which, together with ESP, supervised the project at all stages to verify the results.

Based on the results, the following conclusions were drawn:

- 1) The study **confirmed that it is possible to re-export the amount of gas that is expected to be stored in UTG's gas storage facilities in customs warehouse mode from Ukraine to the EU under the stress-test scenarios. This is possible regardless of whether the evacuation must occur in a shorter period (the more likely option, as indicated by the traders) or if it will take place across the entire winter season, until the end of March 2024.** The severe conditions in the scenarios include both high demand and the technical unavailability of different parts of the gas infrastructure.
- 2) The gas storage and transmission infrastructure have high reliability and resilience due to significant reserve capacities that were used to regulate export regimes during the crisis situations modeled.
- 3) Different combinations of transportation routes between storage facilities and the Ukraine-EU cross-border points were confirmed; these can substitute for one another and allow the quick switching of routes at very short notice.

3. APPROACH TO THE HYDRAULIC MODELING

3.1. DATA CONFIDENTIALITY / SENSITIVITY WORDING

Due to the Martial Law introduced in Ukraine, this public note does not contain any sensitive or detailed technical information that could create additional wartime risks for Ukraine's gas infrastructure.

⁴ Simone Research Group

⁵ Observer role

3.2. INPUT DATA DESCRIPTION

The following input data were used for the hydraulic modeling:

- 1) Domestic consumption distribution by physical point
- 2) Transit flows
- 3) Interconnection points' firm capacities
- 4) UGS withdrawal to EU by point
- 5) Line-pack level
- 6) Pressure limitations
- 7) Compressor station (CS) configurations
- 8) Linear part configuration data
- 9) Gas quality parameters
- 10) UGS injection/withdrawal capacities at various available active gas levels

3.3. DESCRIPTION OF THE STRESS-TEST SCENARIOS

The project working group began by conducting an analysis to define stress-test scenarios for modeling gas infrastructure operations during the 2023/2024 winter season. The chosen scenarios represent a rather pessimistic spectrum of possibilities while taking into account probability level.

The analysis considered the available data about attacks by Russian Federation on energy and gas infrastructure in 2022/2023 as well as their structure and scale. In addition, characteristics of damage to other non-energy/non-gas objects in different regions of Ukraine were taken into account. Based on this information and on the systems' characteristics, the working group defined gas objects that, when potentially targeted, might have the biggest impact on Ukraine's ability to withdraw and transmit stored gas to EU borders.

The main gas pipelines of gas transmission system (GTS) of Ukraine have an available gas flow capacity, and the presence of interconnector pipelines connecting the main transmission lines makes GTS maneuverable and enables diverse gas transportation to serve both Ukrainian consumers and European traders.

The group also analyzed upstream, TSO, and storage system operator (SSO) assets that might become potential targets for Russian strikes and included these data in the model. Ukraine's storage facilities were analyzed along with their technical characteristics, such as vulnerability and stability (number of compressor shops, the possibility of compressorless withdrawal, etc.).

Given this information and data about protection measures the facilities have taken, the working group determined that it is relatively unlikely that storage facilities far from zones of active hostilities would experience full capacity outage. This is because of several factors, including that Ukrainian storage sites are located in geological formations deep underground (from 400 meters to 2 kilometers), they are protected from potential Russian strikes by their depth and natural vegetation, and work via dispersed wells. Therefore, the failure simulated in seven of eight scenarios is considered to be quite pessimistic, but it demonstrates a significant stability margin for resilience.

Additionally, all stress-test scenarios include the simultaneous outage of several transmission objects, which are important for Ukraine's dispatching operations. These can be overtaken by other underutilized CSs,

demonstrating the maneuverability of the Ukrainian GTS to technically guarantee the fulfillment of obligations to both foreign and domestic customers.

To make sure the simulation addresses all scenarios (because capacity for gas withdrawal from the UGSs is higher at the beginning of the autumn-winter season and gradually decreases as gas is withdrawn), all modeled scenarios consider three dates: December 27, 2023; January 31, 2024; and February 29, 2024. At the same time, four options were considered for the availability of active gas in the UGSs. For all modeled scenarios, the assumed level to be withdrawn for the EU during the 2023/2024 season is in line with the injection forecast as of the date of this note.

When developing the scenarios, the working group considered foreign traders' interest in storing gas in the UGS of Ukraine. The greatest attention was paid to the diversity of risks arising in December, which meant developing four scenarios with the full withdrawal of the injected volume forecast under the customs warehouse during November and December. The rest of the scenarios assume linear withdrawal throughout the whole winter season.

The modeling takes into account two options for gas withdrawal from UGSs during the autumn-winter period: standard and cold winters (with different consumption levels), as well as average daily and peak consumption with slightly higher volumes than last season's figures. There is also a scenario that has a normal winter but peak consumption due to a cold spell occurring at the same time as an emergency (damage to infrastructure).

To test the flexibility and reliability of the GTS, scenarios were developed for both current-transit and zero-transit conditions. Seven of the eight scenarios apply the zero-transit option as a pessimistic case to prove that the system would operate smoothly under these conditions. However, the "as-is" transit case is also modeled in the S7 scenario to cover the whole risk spectrum.

Scenarios include decreased gas production after shelling as the conservative assumption compared to average indicators throughout the season; S1 models the outage of numerous upstream facilities, leading to a much higher loss of volume than has ever been registered after attacks on the gas fields starting from February 2022.

Following several rounds of discussions, the working group agreed upon the following stress-test scenarios:

Table 1: Stress-test scenarios

KEY INPUT PARAMETERS	SCENARIO							
	S1	S2	S3	S4	S5	S6	S7	S8
Emergency start date	Dec-27	Dec-27	Dec-27	Jan-31	Jan-31	Dec-27	Feb-29	Feb-29
Seasonal withdrawal for Ukraine (UA) from UGS + re-export to the EU from UGS	Cold winter in UA + expected gas volumes of EU traders	Normal winter in UA + expected gas volumes of EU traders	Cold winter in UA + expected gas volumes of EU traders	Cold winter in UA + expected gas volumes of EU traders	Normal winter in UA + expected gas volumes of EU traders	Cold winter in UA + expected gas volumes of EU traders	Normal winter in UA + expected gas volumes of EU traders	Cold winter in UA + expected gas volumes of EU traders
UA domestic daily consumption during the emergency event	Peak	Normal	Peak	Peak	Peak	Peak	Peak	Normal
Transit volume, million cubic meters/day (mcm/d)	No transit from Russian Federation (RF)	No transit from RF	No transit from RF	No transit from RF	No transit from RF	No transit from RF	As-is	No transit from RF
Re-export of gas from UA customs warehouse to EU	All stored gas by the end of Dec 2023	All stored gas by the end of Dec 2023	All stored gas by the end of Dec 2023	Linear through the entire winter season	Linear through the entire winter season	All stored gas by the end of Dec 2023	Linear through the entire winter season	Linear through the entire winter season
UA domestic production	Significant decrease	Slight decrease	Slight decrease	Slight decrease	Slight decrease	Slight decrease	Slight decrease	Slight decrease
Impact description (simultaneous damage to upstream, SSO, and TSO assets)	Set of specific assets #1	Set of specific assets #2	Set of specific assets #3	Set of specific assets #4	Set of specific assets #5		Set of specific assets #6	

Each of the eight modeled scenarios includes a simultaneous combination of possible emergency events with significant negative impact on Ukrainian gas infrastructure (although these combinations arguably have very low probability) at the same time as stressful market conditions. From a risk-level perspective, the assessment includes military (potential physical damage to the assets), technical (CS outages, availability of emergency repair inventory stock), and weather (below seasonal-average temperatures) conditions, as advised by GTSOU/UTG.

The results of the modeling, which were presented to the working group, sufficiently demonstrate the technical resilience of the TSO's and SSO's systems to fulfill gas transmission and withdrawal needs under severe external conditions during the forecasted 2023/2024 winter season.

3.4. STATEMENT FROM INDEPENDENT TECHNICAL AUDITOR

SRG performed an independent review, verifying scenarios S1 to S8 as per Table I.

These scenarios simulate combinations of variations of production, extraction, offtake, and transit of gas with variations of damage to the upstream, transmission and storage systems. Scenarios are dynamic, lasting five days and eight hours. At the eighth hour, damage is always simulated; the damage lasts for five days to verify that the network can deliver the agreed supplies for this period.

SRG verified the following input parameters:

- 1) Total amount of domestic consumption (normal or peak);
- 2) Volume of natural gas extraction from deposits (and their delivery to the transmission system): significant decrease in one scenario or conservative assumption regarding production in others;
- 3) Volume of transit (as-is in S7, 0 in others);
- 4) Transport volume from UGS to the EU (withdraw all stored volumes by the end of December or linearly through the entire winter season);
- 5) Maximum available UGS withdrawal capacity, which depends on three factors: whether it is a cold winter or a normal winter (determining the degree of UGS withdrawal on a certain date); the UGS withdrawal rate for EU customers (whether customers withdraw all stored volumes by the end of December or linearly through the entire winter season), which also impacts the degree of UGS withdrawal; and the scenario date (December 27, 2023; January 31, 2024; February 29, 2024) (for this purpose, GTSOU prepared a table of 12 values for each UGS); and
- 6) Sets of upstream, TSO, and SSO assets simultaneously damaged under every scenario.

No discrepancies that could have a significant impact on the modeling results were identified.

SRG also checked two other factors:

- 1) Configuration of CSs. All checked are in satisfactory condition; that is, the operating point of the compressors is inside the normal operating range, to the right of the pump line, above the minimum speed line and below the maximum speed line, and to the left of the choke line. Some CSs may be in the maximum state, meaning at maximum speed or maximum drive power.

- 2) Pressures on key Gas Metering Stations, outlets from UGSs, exits from production sites, and customer pressures.

Based on the above, **SRG confirms the correctness and accuracy of the hydraulic models prepared for the stress-test scenario simulation and the UGS facilities' ability to deliver the indicated volumes under these crisis scenarios.**

4. SUMMARIZED RESULTS OF THE COMPLETED STRESS-TEST

The study confirms that **it is possible for Ukraine to re-export to the EU the amount of gas that UTG's gas storage facilities are expected to accumulate in customs warehouse mode. This is possible both over a shorter period (which the traders indicated is the most likely pattern) and throughout the entire winter season, until the end of March 2024.** The maneuverability of Ukraine's gas pipeline system and the reserve capacity of UTG's gas storage facilities provide the ability to deliver the required volumes under all the stress-test scenarios that were considered and modeled.

5. NOTES ON GTSOU/UTG INFRASTRUCTURE CAPACITY

UGS facilities are crucial infrastructure facilities that are commonly used to secure the gas supply during periods of both seasonal and short-term market volatility. This was illustrated from different sides during two previous winters. The beginning of 2022 showed for the EU the problem with having a low level of gas stored in the UGS and depending on one gas supplier, while the beginning of the 2022/2023 winter showed how the UGS can reach a high level of stored gas when mandatory filling levels have been imposed to secure gas for the basic needs of the population and industry.

More than 80 percent of Ukrainian storage's active gas volume (about 25 bcm) is located in close proximity to EU Member States and more than 800 kilometers from the front lines. Moreover, Ukrainian storage sites are located in geological formations deep underground (from 400 meters to 2 kilometers) and protected from potential Russian strikes by their depth and natural vegetation. The storage facilities work via dispersed wells with aboveground equipment at multiple locations. Over the past year, the technical capacity of gas storage facilities in Ukrainian-controlled territory (capability to inject, store, and withdraw gas) has not decreased and meets the level of calculated figures. Most UGS facilities in Ukraine have numerous physical connections to the GTS, which enables the high performance and flexibility of the overall system.

The 2022/2023 gas withdrawal season (November to March) illustrates this capacity and flexibility—the actual daily withdrawal volume did not exceed 80 percent of the maximum capacity, and for most of the autumn and winter (140 out of 151 days), the actual daily withdrawal volume did not exceed 60 percent of the maximum capacity.

Moreover, GTS possesses significant available CS capacities, which would allow it to substitute any CS in case of damage in order to transport gas from UTG facilities to the western border.

The gas storage product is provided within the framework of a single virtual point; therefore, when withdrawing gas, the storage user is not limited by the physical location of the gas (nominations are submitted for entry and exit points to/from UGS in general, not to a certain UGS facility). Moreover, GTSOU provides the availability of relevant capacities at the entry and exit points to/from the GTS.

GTSOU has numerous combinations of gas transportation routes from gas storage facilities to borders with EU countries and has several pipelines at each cross-border point with adjacent EU TSOs. This

increases the security of gas infrastructure usage. Even significant damage to certain parts of the gas transmission network would not fully disrupt its operations because of the vast opportunities to disconnect damaged parts of the system and transport the gas via parallel or bypassing routes.

Moreover, the majority of Ukraine's gas transmission and storage system facilities can operate using gas as fuel, which creates additional confidence that attacks on energy infrastructure would not disrupt gas transportation or services to foreign clients. This was proven by the experience of the 2022/2023 winter season, when even during the full blackout of Ukraine's energy system, gas transportation continued.

6. ADDITIONAL BUSINESS INFORMATION

The storage year is a period of time that starts from the first gas day of April in the current calendar year and lasts until the first day of April in the next calendar year.

JSC Ukrtransgaz was one of the first gas storage operators in Europe to be certified in accordance with the conditions and procedure established by Regulation (EU) 2022/1032 of the European Parliament and of the Council of 29 June 2022 amending Regulations (EU) 2017/1938 and (EC) 715/2009 with regard to gas storage. Ukraine quickly implemented the requirements of the European regulations on the mandatory certification of the SSO to remove risks to the security of natural gas supply in its legislation (the relevant law is effective from January 1, 2023). On January 24, 2023, the National Energy and Utilities Regulatory Commission (NEURC), as the national regulator, adopted a Procedure for Certification of the Storage System Operator, which also details the process of continuous monitoring of compliance with certification requirements. On March 31, 2023, the EnCS issued a positive opinion on the previous NEURC decision on certification, confirming that JSC Ukrtransgaz complies with the provisions of Article 3a (6) of Regulation (EC) 715/2009 of July 13, 2009. On April 7, 2023, the NEURC made the final decision on certifying the SSO JSC Ukrtransgaz.

Annual capacity:

Applications for annual capacity are submitted every year; customers can apply for a period of one to four years.

The volume of available capacity that is subject to allocation is published on the SSO's website by January 1. Customers can submit their allocation applications until February 15 and can utilize their capacity from April 1 after this capacity has been paid for.

Monthly capacity:

By the fifth day of every month, the SSO publishes the available capacities that will be allocated during the next month. Customers can submit their allocation applications until the tenth day of every month.

Useful links:

- 1) Guideline for capacity allocation by SSO:
<https://utg.ua/en/utg/gas-transportation-system/capacity.html>
- 2) SSO tariffs:
<https://utg.ua/en/utg/business-info/tariffs.html>
- 3) SSO customs warehouse service:
<https://utg.ua/en/utg/gas-transportation-system/customs-warehouse-service.html>

- 4) Aggregated Gas Storage Inventory (AGSI) portal:
<https://agsi.gie.eu/data-overview/graphs/VGS--UGS-UKRAINE/UA/21X0000000013279>
- 5) How to become a customer of SSO
<https://utg.ua/en/utg/gas-transportation-system/how-to-become-a-customer.html>
- 6) Booklet of SSO of Ukraine
<https://utg.ua/en/utg/gas-transportation-system/underground-gas-storage.html>
- 7) Guideline for capacity allocation by TSO:
<https://tsoua.com/en/business-services/order-and-payment/capacity-allocation-at-interconnection-points/procedure-for-conducting-auctions/>
- 8) TSO tariffs:
<https://tsoua.com/en/business-services/tariffs/transmission-tariffs/>
- 9) TSO Shorthaul product:
<https://tsoua.com/en/business-services/order-and-payment/capacity-allocation-at-interconnection-points/shorthaul/>
- 10) TSO Transparency platform:
<https://tsoua.com/en/transparency/test-transparency-platform/>

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⁶ Observer role

⁷ Certified SSO under 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, as adapted and adopted in the Energy Community <https://eur-lex.europa.eu/eli/reg/2022/1032/oj>

⁸ Certified TSO under Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas, as adapted and adopted in the Energy Community